METALLURGIA

THE BRITISH JOURNAL OF METALS

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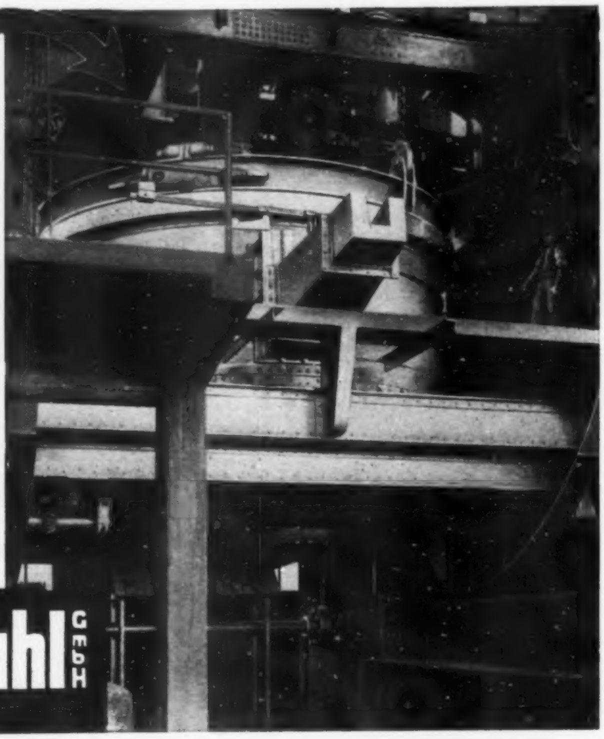

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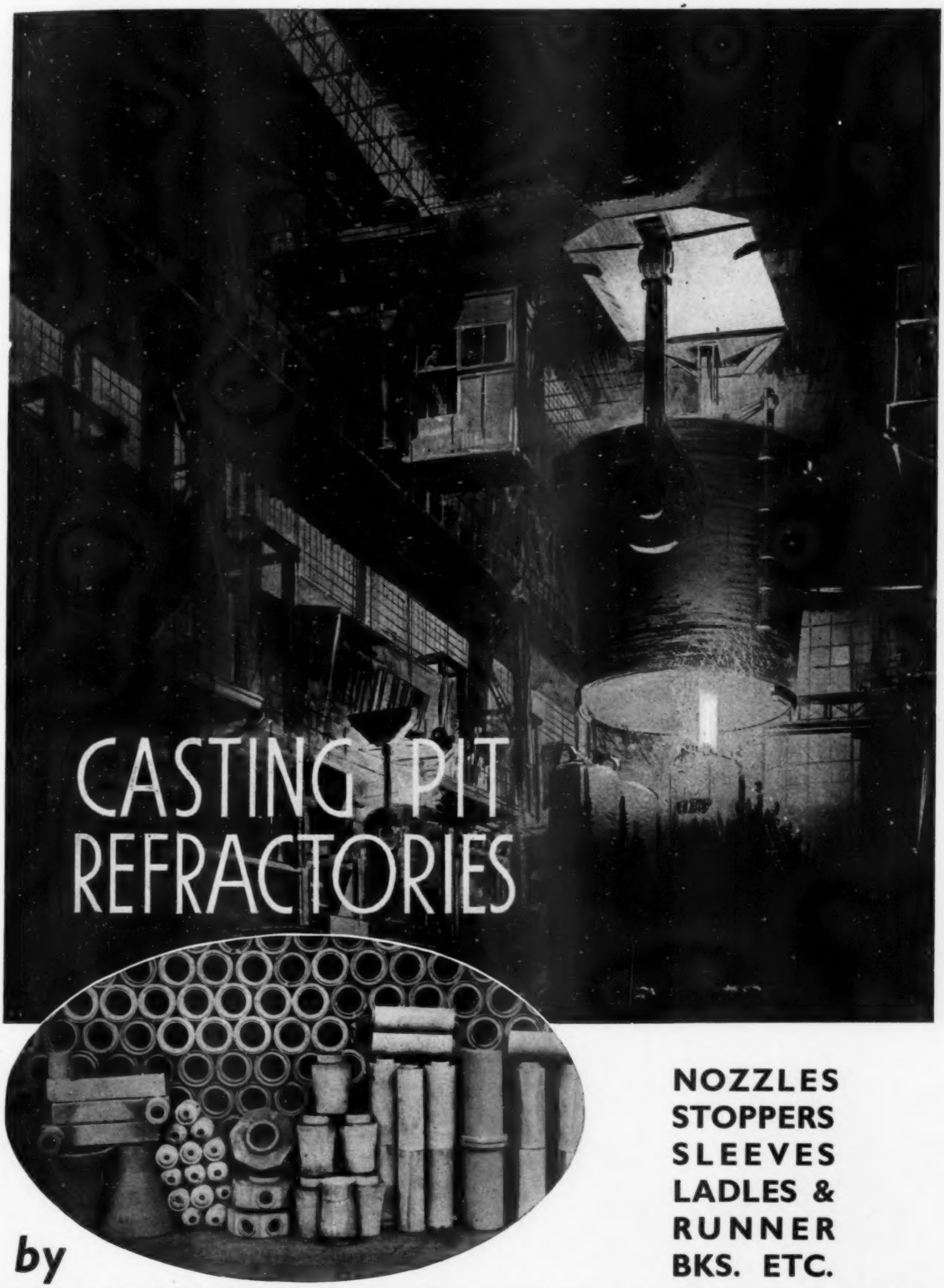
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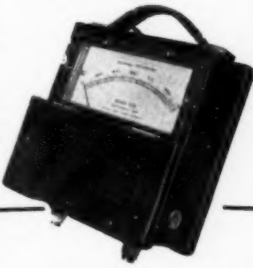

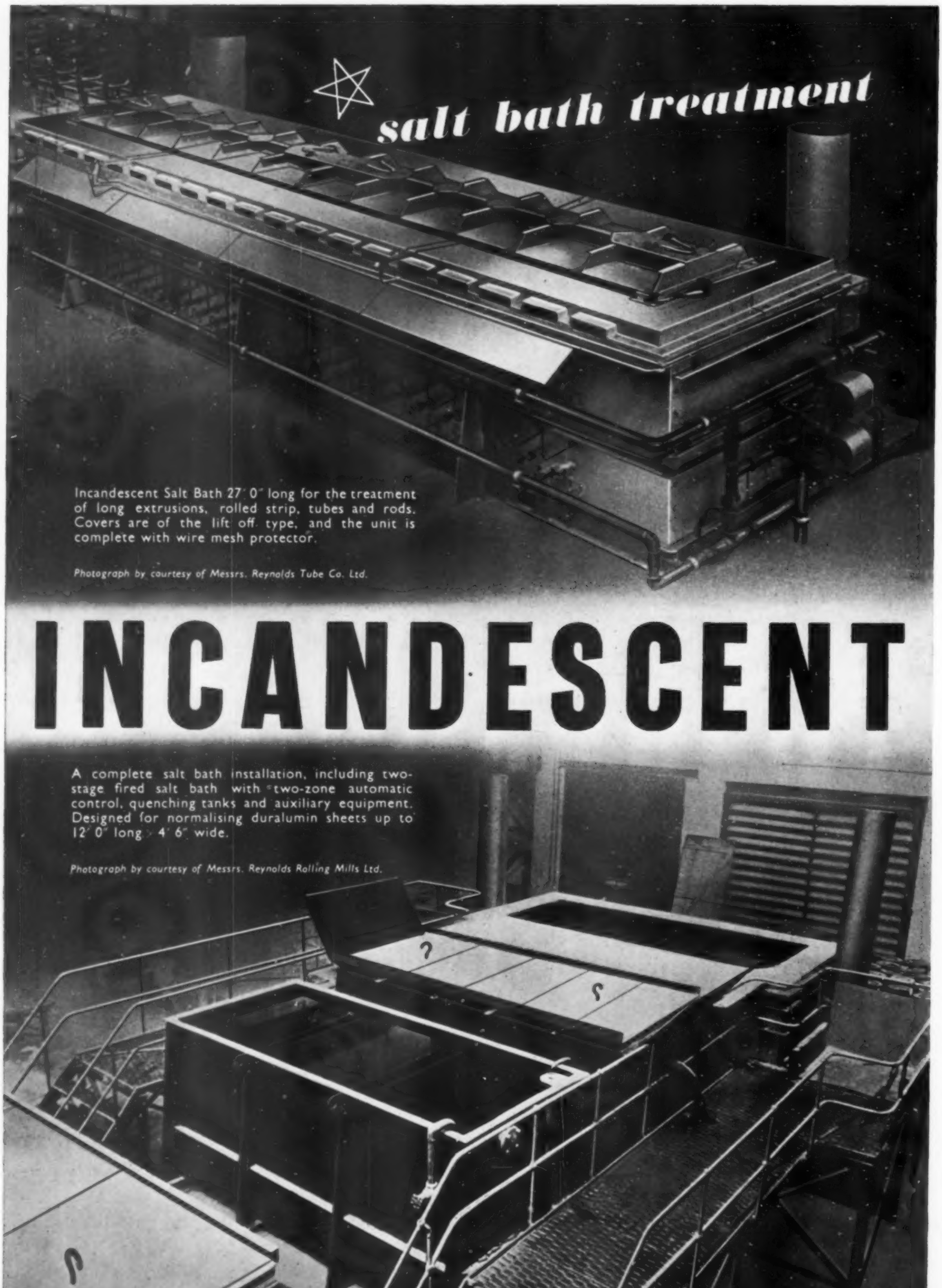
salt bath treatment
Incandescent Salt Bath 27′ 0″ long for the treatment of long extrusions, rolled strip, tubes and rods. Covers are of the lift off type, and the unit is complete with wire mesh protector.
Photograph by courtesy of Messrs. Reynolds Tube Co. Ltd.
INCANDESCENT
A complete salt bath installation, including two-stage fired salt bath with two-zone automatic control, quenching tanks and auxiliary equipment. Designed for normalising duralumin sheets up to 12′ 0″ long × 4′ 6″ wide.
Photograph by courtesy of Messrs. Reynolds Rolling Mills Ltd.

METALLURGIA

The British Journal of Metals

(Incorporating The Metallurgical Engineer.)

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

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AUGUST, 1939. VOL. XX, No. 118.

The famous Forth Bridge, one of the first to be constructed in steel.

Steel in Structural Engineering

By Wm. Ashcroft

Probably the greatest single outlet for steel is in the construction of vital parts of buildings and other substantial erections. This article briefly traces the development of structural materials and deals with the contribution made by steel to this branch of civil engineering.

STRUCTURAL engineering to-day has a very wide application, but originally it was applied to a branch of civil engineering concerned primarily with bridges and large buildings. It came into use with the application of iron and steel for these purposes, and was used to distinguish these structures from those in wood or stone. It embraces the design and construction of all those vital parts of buildings and other substantial erections in which a knowledge of the strength and nature of materials used and of the principles of mechanics are the controlling factors. Modern progress in structural engineering has coincided with parallel developments in the production of iron, steel and Portland cement, upon which it is dependent. Developments in the science of mechanics and in the theory of elasticity have occupied a longer period of time.

Towards the end of the 18th century cast iron began to displace stone in the construction of bridges, although Smeaton had advocated the use of this material in 1755, but then, as to-day, revolutionary methods of construction were only accepted after sound evidence of their advantages gave adequate assurance, and progress in this direction was slow. However, as the end of the century approached, much experience had been acquired in the production of a uniform and reliable material and in the possibilities of the use of cast iron in buildings.

Probably the most striking application of cast iron occurred in the construction of arched bridges, the first bridge of this kind being completed at Coalbrookdale in 1776. Later, with increased knowledge of the material, the cast-iron units were made in longer sections and bolted together. Considerable development took place about this time in the use of cast iron in factory buildings, first as columns to support timber beams, and later as beams to substitute the timber. At the commencement of the 19th century a building was designed and erected in Manchester in which cast-iron beams were supported on cast-iron columns, while the floors consisted of brick arches supported on the bottom flanges of the beams and levelled off with rough concrete. Buildings of this type became quite common, and there was little change of type for a long period. At first the underlying principles of this form of construction were little understood, but after much experimental research by such men as Fairbairn, Tredgold and Hodgkinson the development of sound principles assisted progress.

Although the production and application of cast iron was a tremendous step forward, great improvements in the manufacture of wrought iron, which followed upon the introduction and development of the puddling furnace and the rolling mill by Henry Cort, near the end of the 18th century, led to its increased use in construction. It is probable that the investigations on the strength of cast iron revealed factors which stimulated the more effective use of wrought iron; certainly, in theory, it was regarded as approximating more closely to the ideal elastic material for constructional purposes. However, only the simplest sections in solid wrought iron were rolled at that time, whereas columns and beams in cast iron could give the size and shape considered to be desirable for the loads they were required to bear.

Many years passed before developments in the rolling of wrought iron resulted in the production of a joist. A small rolled joist was produced by Ferdinand Zores in 1847, while larger rolled sections were on view at the Paris exhibition of 1855; joist sections had been advocated by Fairbairn, and were first rolled in England by Dorman and Long in 1855. The small rolled joists, produced in these early days, were largely used in France as the basis

Courtesy of Dorman, Long & Co., Ltd.

Birchenough Bridge over Sabi River, Rhodesia, made in alloy steel possessing a strength 50% greater than mild steel generally employed.

of fire-resisting floor construction, but these sections came very slowly into general use. It is noteworthy that the Harper building in New York, built in 1854, was probably the first one to have wrought-iron beams set in masonry walls as lateral supports.

It is not easy to realise that up to about 1860 the use of steel for structural purposes was practically unknown, and cast and wrought iron were still supreme. About 1856 Henry Bessemer patented his method of steelmaking, which was destined to revolutionise production and open up new engineering possibilities. Unfortunately, the early Bessemer steel was "red short," and the finished ingots would not forge. Many metallurgical difficulties were overcome by Musket's plan of adding ferro-manganese, which produced the well-known forging qualities associated with this steel.

The introduction of the Bessemer process and, later, the Siemens-Martin process led to the production of cheap and reliable mild steel, but prejudice and early difficulties in manufacture delayed its use. As late as 1877 the English Board of Trade Regulations prohibited the use of mild steel in bridge construction; but the value of mild steel gradually overcame prejudice, and as the difficulties in manufacture were reduced, its application for structural purposes developed rapidly. Probably the greatest impetus to its use for these purposes resulted from the successful construction of the Forth Bridge.

From an engineering point of view this famous bridge, the work of John Fowler and Benjamin Baker, marks an epoch in the history of bridge building. Its enormous clear spans of 1,700 ft. between supports were rendered possible by the use of steel and by the cantilever design of superstructure. Work was commenced on this bridge in 1883, and it was opened for railway traffic in 1890. Well over 50,000 tons of steel were used in its construction. The success of this venture constitutes a remarkable tribute to the skill of the structural engineer at that time, and a testimony to the fitness and reliability of mild steel as a structural material for bridge-work and general constructional use. Incidentally, this bridge will long remain a tribute to British skill in the application of steel.

The extended use of steel for structural purposes was assisted and guided by the introduction of standard forms and dimensions and by uniform specifications. Progress in this direction was largely initiated in America, where the Society of Civil Engineers in conjunction with steel manufacturers contributed greatly to the development of standard formulæ. The Carnegie-Phipps Co., of Pittsburgh, published in 1894 a handbook of standard shapes, which incorporated valuable information and formulæ regarding their structural properties. These remained standard for many years, and provided the basic information for many subsequent handbooks published. In England specifications were issued by the British Engineering Specifications Association, formed in 1904, and the London County Council General Powers Act of 1909 provided the first authoritative regulations for the control of the design of steel-framed buildings.

Since the erection of the Forth Bridge the use of steel in bridge construction has made enormous strides, and, although the use of mild steel still predominates, in recent years there has been a growing interest in the use of low-alloy, high-tensile steels for this purpose. An early application of high-tensile steel in bridge construction was in the Birchenough Bridge, over Sabi River, in Southern Rhodesia, in 1935. This bridge crosses the Sabi River in a single span of 1,080 ft. and forms a link in the roadway to Umtali. The material for all the structures was made and fabricated on Tees-side by Dorman, Long and Co., Ltd. Chromador high-tensile steel was used throughout the arch, which enabled the engineers to obtain a lighter structure for a greater span than had previously been possible. At the time of its construction this bridge represented a material advance in the science of long-span bridge building, and successfully demonstrated the possibility of producing a structure of great span—the third largest arch in the world —at a cost no greater than that of a series of short spans.

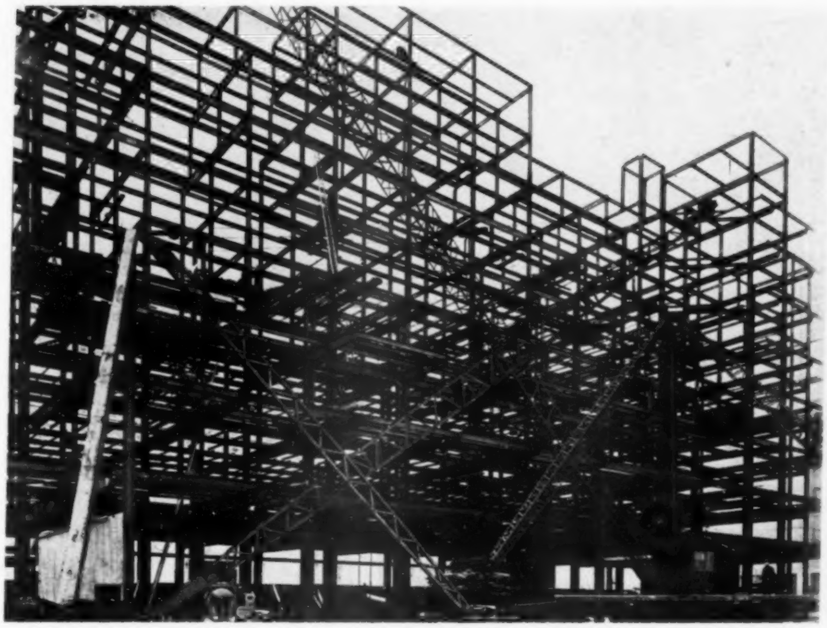
Of the many bridges which have since been built, high-tensile steels have usually been employed to a varying extent. Mention may be made of the Storstrom Bridge, in Denmark, which is on the main route between Copenhagen and the Continent. It crosses the Storstrom, which separates the Islands of Masnedo and Falster, the distance from shore to shore being approximately $2\frac{1}{4}$ miles. This bridge, which carries a single line railway track, a roadway and a footway, required over 21,000 tons of steel, chiefly Chromador high-tensile steel. It comprises 47 approach spans, which are built of steel-plate girders of the deck-cantilever type, and three navigation spans which have steel-plate girders reinforced with a polygonal arch. The centre navigation span gives a clear opening of nearly 450 ft. and a clear headway of 86 ft.; the two side

Storstrom bridge on the main route between Copenhagen and the Continent.

Courtesy of Dorman, Long & Co., Ltd.

navigation spans have openings of 335 ft. The steelwork was manufactured and fabricated in the Middlesbrough shops of Dorman, Long and Co., Ltd., who also carried out the floating out and erection of the steelwork on the site.

Although mild steel is used in bridge building in large quantities, the use of high tensile steels, and also special low alloy steels developed to reduce corrosion is growing. In addition to silicon and chromium steels, copper steels and also copper-chromium steels are used. In buildings, however, the use of low alloy steel in structural work is negligible, practically all structures being in low carbon steel.



The steel framework of the Headquarters of the London Fire Brigade.

Any reference to metal-framed buildings should not omit those erected by Paxton for the 1851 Exhibition in Hyde Park, and known as the Crystal Palace buildings. These are not usually claimed as one of the early examples of iron-framed buildings, but the structures were remarkable in having foreshadowed and established a principle adopted in the modern steel-framed building in which the walls do not transmit any important portion of the structural load to the foundation. It was, however, the developments which took place at a later date in America that proved to have the most marked influence on the progress of this form of construction throughout the world.

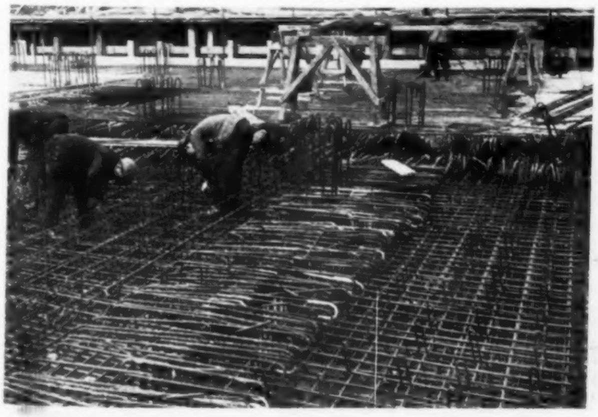
In the earlier days of steel-frame construction applied to buildings, parts and connections were often so designed and fabricated that protection against corrosion was difficult or impossible of application, and in later developments considerable attention was given to the dangers which might result from this cause. Failures have in fact occurred owing to corrosion, but the demolition of some of the earliest buildings have shown that with reasonable care the life of the ordinary type of steel-framed building will have no particular limit if the work is properly done. Gradually, however, investigations have led to the recognotion of the value of concrete as a suitable and effective encasing material for the protection of steel.

In addition to its use as an encasing material for the protection of steel against fire, concrete, suitably reinforced, has made remarkable progress in recent years for large buildings. The use of concrete for structural work is not by any means new, since it was used by the Romans for the construction of aqueducts, bridges and other massive work, but ferro-concrete work is a more recent development. The introduction of reinforced concrete is generally attributed to Monier, who, in 1868, developed the idea of strengthening concrete by incorporating in it a network of small iron rods for the purpose of constructing water basins. Many other investigators have contributed to the scientific development of the combination which is now almost indispensable in structural engineering.

Generally, the adoption and development of construction in reinforced concrete has followed the lines common to steelwork, since the theoretical basis is almost identical, and from these broad theoretical considerations and the results of many experiments and much experience, laws have been formulated which enable reinforced concrete members and parts to be accurately and economically proportioned for the purpose they are required. Reinforced concrete buildings are usually of the framed type of construction consisting of pillars and beams as in steelwork, but the wall and floor panels are continuous between the columns and beams, so that the concrete enclosing the reinforcing steel is continuous and the structure is monolithic in character.

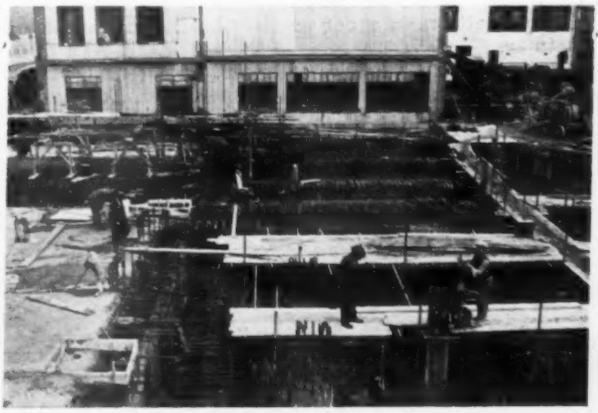
Steel reinforcement in connection with a factory shelter under construction.

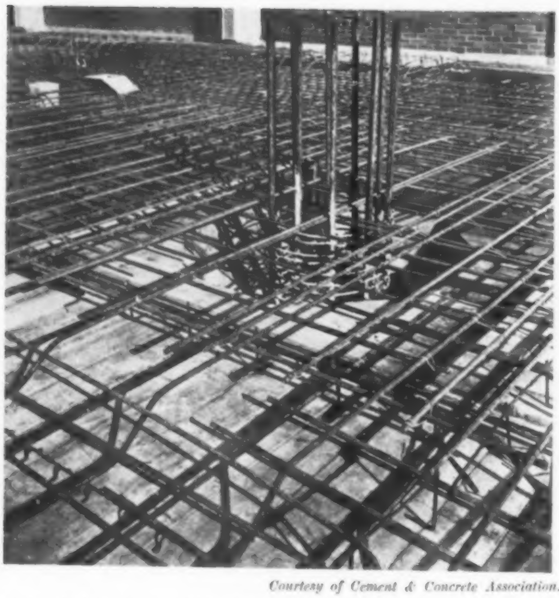
Courtesy of Cement & Concrete Association.



General view of reinforcement of a structure on the Great West Road. The concrete is being placed by chuting.

Courtesy of Cement & Concrete Association.





Courtesy of Cement & Concrete Association.

Steel reinforcement for floor and column of a factory under construction at Southall.

Courtesy of Williams & Williams Ltd.

Berkeley Square House, London, the largest block of office buildings in Europe. A reinforced concrete construction fitted with steel doors and windows.

Reinforced concrete buildings provide a substantial outlet for mild-steel rod and bar, and the accompanying illustration, Berkeley Square House, is claimed to be the largest block of office buildings in Europe of this type. It comprises four main blocks of 11 floors each, and a central tower at the back, 145 ft. high, occupying a site of 80,500 sq. ft. The construction throughout is of reinforced concrete, including retaining walls, floors, staircases and lift shafts. In addition to the steel used for reinforcing the concrete, it is noteworthy that this building is equipped throughout with 1,640 steel windows and doors. This structure is typical of modern buildings which constitute one of the biggest outlets for mild steel.

Containers for Synthetic Resin

SYNTHETIC resins are of primary interest to varnish makers for their use in the compounding of surface coatings, and the small sizes in which batches are processed make possible metal contamination a more potent factor than would be the case when large lots are being produced, and for later dilution.

Kettles and other vessels used in these processes demand good corrosion resistance and strength at high temperatures. Metallic impurities are introduced into these products either from corrosion or the process of wear of the equipment.

Nickel, Monel and Inconel have been found highly satisfactory for these processes. They have resistance of a high order to corrosions in reactions making use of alkyd, phenolic and modified phenolic resins. Nickel is used both in solid and as nickel coating and has some special merit where the clarity of the resins must be preserved during the various stages; Monel is used for vessel construction, particularly if resistance to corrosion is placed before colour retention; and Inconel appeals more strongly to the synthetic resin producer than to the varnish manufacturer.

250-gallon truck kettles of Monel, with $\frac{3}{16}$ in. bottoms, are used for varnish production; plastics reaction vessels of solid nickel and fitted with nickel pipe and nickel clad steel processing kettles are employed in the production of phenolic resin plastics. Further application of these metals is shown by the use of 50-gallon steam jacketted Monel kettles for the manufacture of a phenol-formaldehyde resin.

Tests were carried out for ascertaining corrosion resistance of these, and other, metals. The tests made use of spool type specimen holders and machined metal discs which were held in place through porcelain and glass insulators supported over Monel rods. These tests were made in alkyd resins, resin modified phenolics, and natural resins and ester gums. The results showed that where freedom from action on the colour of the finished product and greatest apparent durability were considered of equal importance, then Nickel rates as the preferred material. There is the danger of buckling and subsequent failure of kettle bottoms through their prolonged exposure over cooking fires, and the high strength of nickel, Monel and Inconel at elevated temperatures is a strong factor in avoidance of such failures, curves for short period tests for tensile strength of all three metals showing no significant changes in their strength over the range from room temperature to 600°F. and only slight reductions below that temperature.

R. T. Barnes, jr. *Ind. and Eng. Chem.* Vol. 31, No. 7, July, 1939, page 847.

Honeywell-Brown Ltd.

THE new works of Messrs. Honeywell-Brown Ltd. at Greenford, Middlesex, permits a considerable amount of manufacturing and assembly to be carried out in this country. In addition to controlling and recording instruments used in the fields of air-conditioning, heat and ventilating, probably the biggest percentage of the instruments manufactured by this Company are installed in steel works. For instance, the new steel mill of Richard Thomas and Co. Ltd., at Ebbw Vale, has probably the largest installation of controlling and recording instruments in this country, and these were made by Honeywell-Brown Ltd. In addition to several outstanding instrument installations in various steel mills, this Company is at present equipping the John Summers' strip mill at Chester with the necessary instruments as applied to the soaking pits, slab heaters, annealing furnaces, etc.

Maurice G. Parker, Ltd., which for nearly twenty years has specialised as consultants in technical advertising, has transferred to larger and more convenient offices at 3, New Street, Birmingham. Telephone and telegraphic addresses remain the same as previously—viz., MIDLand 2014 and "Technikad, Birmingham."

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Creep Resistance

THE continuous deformation of metals when subjected to more than a certain constant load is defined as "creep," and many metals possess this characteristic under stress at atmospheric temperatures. It is not surprising, therefore, that the increasing tendency of engineers to use high-pressure, superheated steam and the growing use of structures at elevated temperatures have necessitated considerable research by metallurgists in an effort to meet demands by the provision of suitable materials. In modern superheated steam practice, steam temperatures in some cases are as high as 500° C., and, for many other purposes, much higher temperatures are in use. Stresses imposed on materials at such temperatures present many problems, especially in view of the fact that metals under such conditions cease to be elastic substances and are subject to "creep" under the effect of sustained loading.

Research on the behaviour of metals at high temperatures has led to the solution of many of these problems and has been responsible for the development of new steels which resist creep. The value of this research work is demonstrated by the increased fuel economy effected by central generating stations which are now able to raise steam temperatures to about 500° C. and to pressures as high as 1,500 lb. per sq. in., because of the stronger steels now available. Although there would appear to be little cause for anxiety as regards the retention of adequate strength in steels up to temperatures of, say, 300° C., it is now well known that from such temperatures upwards there is an appreciable lowering of the strength, which rapidly becomes more serious with increasingly higher temperatures. The response of different steels under high temperatures, when subjected to stress over varying periods of time, is engaging the attention of investigators throughout the world.

An interesting contribution to this subject of creep was given in a paper by Mr. R. F. Miller before a recent meeting of the Metropolitan Section of the American Society of Mechanical Engineers. Dealing with the strength of metals at elevated temperatures, he briefly outlined crystal structure and the phenomenon of slip by groups of atoms displaced simultaneously, and stated that the slip lines are evidence of plastic deformation of the metal accompanied by strain hardening. Referring to the opposing processes of softening and strain hardening, he lead up to a consideration of the temperature at which these two opposing processes balance and which may be called the "transition temperature." It is his contention that the fundamental difference between the behaviour of most metals under a given applied stress at atmospheric temperature and at elevated temperature is that at atmospheric temperature most metals begin to flow, but are gradually strengthened by strain hardening and finally cease to flow, whereas at any temperature above the transition temperature they continue to flow. This continued flow of metals under stress at high temperature is called "creep." In either case, if the stress is increased sufficiently, the metal will break.

It is shown that the rate of creep of a metal at temperatures above its transition temperature is proportional to the stress, and that strain-hardened metal is weaker at high temperatures than metal which is free from strain-hardening, as the metal is being operated at a temperature above its recrystallisation temperature. It is asserted that creep is partly, at least, a crystallographic rearrangement of the atoms and therefore any force which tends to speed up this rearrangement will coincidentally increase the creep rate.

A number of very interesting and informative conclusions are reached. The question of the time factor in testing is, of course, one of vital importance and mention was made of the fact that some such tests have been run for more than five years and that most investigators now agree that reliable indications call for tests over hundreds, if not thousands, of hours.

Although metals at ordinary temperatures are stronger the finer the grain, yet above the transition temperature the coarser grained metals show the greater resistance to creep. This is accounted for by the fact that the grain boundaries are weaker than the actual grains, at that temperature, and the coarser metal has a smaller number of grain boundaries for a given volume. Increase in creep strength by coarsening the grains has been found experimentally in lead, zinc, aluminium, silver, brass and steel; and the type of deoxidation practice employed in making a steel affects the grain size observed after a given heat-treatment. It is also shown that the creep strength of supposedly similar material obtained from different sources may vary within wide limits if the chemical composition, heat-treatment and grain size are not closely controlled.

However, it is noted that the amount of creep in most structures used at elevated temperatures is negligible, failure seldom resulting from creep alone. Failures in parts used under stress at elevated temperature generally occur because of corrosion, excessive local overheating, or a combination of alternating stresses, corrosion, and creep. Failure due to corrosion generally means that the alloy content of the metal has been too low for the particular application. Excessive local overheating may be due to an accumulation or reaction product which decreases the rate of heat transfer, or to improper furnace design and flame impingement. Whenever parts are subjected to alternating stresses at high temperatures, corrosion fatigue may cause early failure.

Creep strength of specimens of the same bar of a low carbon 0·50% molybdenum steel varied from 30 to 40% by different methods of heat-treatment, the weakest condition, in regard to creep, being when the steel was air-cooled from 900° C., which gave a microstructure of ferrite and pearlite, a microstructure which is unstable at 600° C.

Short time creep tests, it is adduced, may show that one material is stronger than another, over the period of the test, but are little more revealing than an ordinary tensile test on the material at high temperature, and cannot show the effects of the slow changes of microstructure.

[We are indebted to the many readers who advised us of the typographical error in the name of the author of the editorial on "Steel" in our last issue. Mr. W. J. Brooke, J.P., is too well known for the error to have passed unnoticed, but we regret the oversight and trust he has not suffered any inconvenience because of it.]

Forthcoming Meetings

The Institute of Metals

The Thirty-First Annual Autumn Meeting of the Institute of Metals will be held in Glasgow from September 5 to 8 inclusive, by kind invitation of the Scottish Local Section, with the co-operation of the civic and technical authorities in Glasgow and the principal Scottish industrialists. The programme arranged includes technical meetings, visits to works, and entertainments. The following papers will be presented for discussion at the technical sessions :—

"The Thermal Conductivity of Some Industrial Alloys of Copper and Nickel," by J. W. Donaldson.

"The Anodic Oxidation of Aluminium," by J. W. Cuthbertson.

"The Direct Oxidation of Zinc," by W. H. J. Vernon, A. I. Akeroyd and E. G. Stroud.

"The Production of Tarnish-Resistance by the Electrolytic Deposition of Beryllia, with Special Reference to Silver," by G. H. S. Price and G. J. Thomas.

"Dentritic Structures. Part I ; The Influence of Crystal Orientation," by L. Northcott and G. T. Thomas.

"A Contribution to the Study of Segration in Copper-Silver Alloys," by S. W. Smith and J. H. Watson.

"Alloys of Magnesium. Part VIII ; A Further Study of the Mechanical Properties of Some Wrought Alloys," by J. L. Houghton and A. E. L. Tate.

There will be a general discussion on Machinability, based on a series of papers published in the August issue of the Institutes monthly Journal.

The Autumn Lecture on "Aluminium and Highland Water Power" will be delivered by Mr. W. Murray Morrison.

The Iron and Steel Institute

The Autumn Meeting of the Iron and Steel Institute will be held in Cardiff from September 12 to 15 inclusive, by kind invitation of the Iron and Steel Industries of South Wales. An interesting programme of technical meetings, works visits, excursions and entertainments has been arranged. The papers to be presented include :—

"An X-Ray Investigation of the Iron-Rich Nickel-Iron Alloys," by A. J. Bradley and H. J. Goldschmidt.

"Niobium-Iron Alloys," by R. Genders and R. Harrison.

"The Causes of 'Roll Marks' on Tinplate," by R. Griffiths.

"The Influence of Steel-Base Composition on the Rate of Formation of Hydrogen-Swells in Canned Fruit Tinplate Containers," by T. P. Hoar, T. N. Morris, and W. B. Adam.

"Transformation of Austenite on Cooling ; Morphology and Genesis of the Aggregates Formed," by H. Jolivet.

"Antimony in Mild Steel," by B. Jones and J. D. D. Morgan.

"Decarburisation of Granulated Pig Iron ; The R.K. Process," by Count Bo Kalling and Ivar Rennerfelt.

"The Effect of Casting Temperature on the Primary Microstructure of Cast Irons. Theories of Dentrite Formation and of the Solidification of Iron-Carbon Alloys," by A. L. Norbury.

"Tensional Effects of Torsional Overstrain in Mild Steel," by H. W. Swift.

In addition to the above papers the Ninth Report on the Heterogeneity of Steel Ingots will be presented for discussion.

Aluminium Congress at Zurich

The Second Aluminium Congress will be held at the Swiss Federal Institute of Technology, Zurich, on September 12 to 14 inclusive, under the auspices of Professor Dr. A. Rohn, Chairman of the Board of the Institute. It will be held in conjunction with the Swiss National Exhibition in Zurich. The object of the Congress is to provide a comprehensive and scientific survey of the production of aluminium, to present the most modern and economic methods of working this metal and its alloys, and to direct attention to its manifold uses.

A very comprehensive range of lectures covering the more recent developments in research work, in production, manipulation and application of aluminium has been arranged, which, in addition to the opening address by Prof. Dr. A. Rohn, includes lectures by Prof. Dr. A. Portevin, of Paris ; Prof. Dr.-Ing. M. Haas, of Berlin ; Prof. Dr. C. Panseri, of Milan ; Prof. Dr. J. Czochralski, of Warsaw ; Freeman Horn, of London ; Prof. Dr. W. D. Triadwell, of Zurich ; Prof. Dr. A. von Zeerlader, of Zurich ; Dr. K. Scherzer, of Lammersdorf, nr. Aix-la-Chapelle ; Direktor F. Efzmann, of Cologne ; Dr. P. Brenner, of Hanover ; A. Vernet, of Geneva ; A. G. C. Gwyer, B.Sc., Ph.D., and P. C. Varley, M.A., of Warrington ; A. G. C. Gwyer, B.Sc., Ph.D. and N. D. Pullen ; Col. W. C. Devereux, of Slough ; Dr. R. Seligman, of London ; Prof. Dr. W. Köster, of Stuttgart ; Prof. Dr. G. Masing, of Göttingen ; Prof. Dr. M. Roš and Dr. E. Bradenberger, of Zurich ; Dr. Kaiser, of Jena ; Dr. Th. Wyfz, of Zurich ; Dr. R. Bertchinger, of Aix-la-Chapelle ; Prof. Dr. E. Schmid and H. D. Graf v. Schwernitz, of Frankfort-on-Main ; G. G. Gauthier, of Chambéry ; Prof. Dr. M. Frh. von Schwarz, of Freiberg in Saxony ; Dr. M. Koenig, of Zurich ; Prof. G. Chaudron, of Paris ; Dr. phil. habil. M. Hansen, of Berlin-Borsigwalde ; Dr. M. Schenk, of Basle ; and Prof. C. F. Keel, of Basle.

The programme includes a visit to the Research Laboratories of the Aluminium-Industrie A.-G.

International Aeronautical Congress

Considerable progress has been made in making arrangements in connection with the above Congress being organised by the Royal Aeronautical Society for July 8 to 12 inclusive next year at Stratford-on-Avon. A tentative programme indicates eleven papers and five discussions ; among the authors of papers in the British section are included Sir Henry Tizard, Professor B. Melvill Jones, Professor L. Bairstow, Mr. A. C. Campbell-Orde, and Mr. Relf, whilst distinguished authorities in Germany, Italy, France and U.S.A. have promised to contribute.

Considerable attention is being given to the social side of the programme, for which Stratford-on-Avon is ideally suited, but since the Congress is being held at the peak of the season when there is a large visiting population, the organisers are anxious to know at the earliest possible date, preferably by September 1, the approximate numbers likely to enrol as members and associate members proposing to attend this Congress. Readers likely to attend are advised to communicate with the Organising Secretary, Mr. I. A. E. Edwards, 4, Hamilton Place, Piccadilly, London, W. 1. It will be clearly understood that the organisers are endeavouring to form a basis regarding the scale on which to organise and any statement sent to the Secretary regarding possible attendance will not be regarded as in any way binding.

Obituary

It is with deep regret that we announce the death of Mr. Eric P. Barfield, the Chairman and Managing Director of Messrs. Wild-Barfield Electric Furnaces Ltd., on August 7, after a short illness. The fact that it is less than a year since Mr. Arthur Barfield passed away will have intensified the blow and his loss will be keenly felt by his colleagues as well as by the many friends with whom he came into contact.

We also regret to announce the death on August 6, of Mr. S. D. White, a Director of the General Electric Co. Ltd. Only last year Mr. White was the recipient of a silver salver presented by Lord Hirst and his colleagues on the Board to mark the completion of 50 years service with the Company. He will be especially missed by his colleagues in the bell, telephone and radio departments.

The Advantages of Heat Treatable Aluminium Bronze Rod

By E. E. Halls

Many problems in engineering construction can be solved by the use of heat-treatable aluminium-bronze alloys. Some alloys of this type are discussed, and information given on their heat-treatment. The results of some comparative corrosion tests are also given.

ALUMINIUM bronzes, for many reasons, provide an range of alloys attractive to engineering in all its branches. The most useful of them, however, are those within a narrow range of compositions which, by virtue of such composition, are responsive to heat-treatment operations akin to those of hardening and tempering, as applied to steels. The commercial limits of this composition are 9·5 to 13·0% of aluminium, with, in general, the remainder comprising copper, with impurities such as iron inevitably picked up in founding, due to its high degree of solubility, and manganese employed as a deoxidiser. Often, however, elements such as lead, nickel, iron and manganese are intentionally added to confer specific properties. In all cases the effect of these additions can be compensated by a slight reduction in the aluminium content. Typical official specifications are DTD 160, 164 and 197.

Aluminium bronze of this type is metallographically simple and well understood, and can contain three constituents—α, β and δ. The α is a relatively soft, ductile ingredient; β is hard in comparison at ordinary temperatures, but ductile for hot-working; δ is comparatively hard. Below 570° C. the stable phase is a duplex one of α plus δ. When heated above 570° C. the α plus δ constituents change into β, or into α plus β, and to conserve this changed condition rapid cooling from above 570° C. is essential. Reheating for a period below 570° C. promotes reversion to α plus δ, but completion of this change would require a long soaking period. In commercial practice, to minimise the time involved, the reheating temperature is usually of the order of 650° C., with slow cooling off in the furnace. Such practice causes a coarsening of the α constituent, and a more uniform and pronounced distribution of the δ constituent.

These changes in aluminium bronze can be more clearly demonstrated by reference to micrographs, and, consequently, a number of these are discussed below.

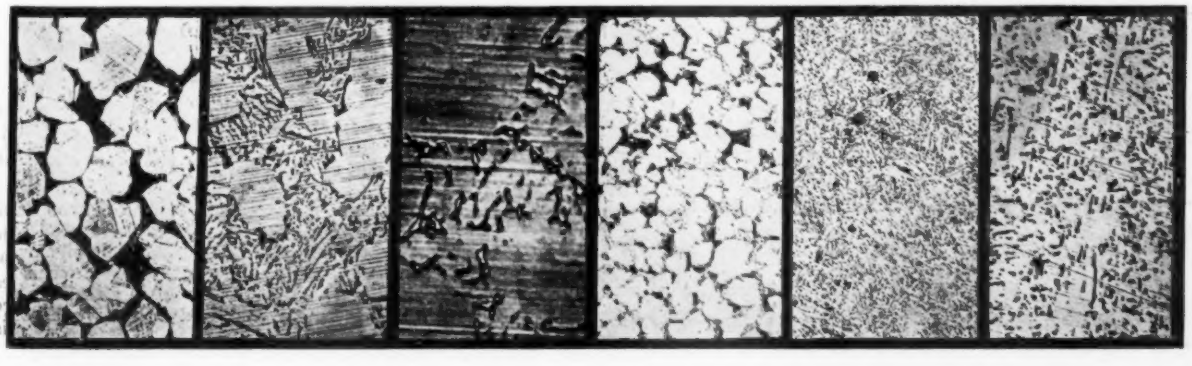
A typical structure of a straight aluminium-bronze extruded rod (aluminium content 10·53%) "as received" is shown in Fig. 1. It shows the massive structure of the α phase embedded in a groundwork of α plus δ constituents. Considerable evidence of a tendency to twin is apparent. The hardness of this specimen was 189 DPN. While this is typical of structure found in extruded bar, a wide variation in grain size is experienced from bar to bar, and often from one end of the same bar to another, due to differential rates of cooling in the extrusion process, both of the bar itself and of the billet in the extrusion press. Bearing in mind this lack of uniformity, and the fact that the massive grain does not give the requisite confidence for the production of small components for arduous service conditions, heat-treatment for refinement of the structure and rendering it more uniform becomes desirable.

The structure of a hardened and tempered specimen is shown in Fig. 2. It was hardened at 865° C., quenched in water, and then reheated to 640° C. for a period of 30 mins., cooling off in the furnace. The specimen has been almost completely resolved into α plus δ constituents with appreciable grain growth. The large masses are primary α and hardness was 181 DPN. Fig. 3 shows the same specimen at a magnification of 600, in which the δ constituent is shown more clearly in relief.

In the case of the 10% aluminium bronzes containing intentional lead addition, 1 to 2% being added specifically to improve machining rates, similar general observations apply. A leaded, free-cutting aluminium-bronze rod (aluminium 9·65%, lead 1·15%) in the "as-received" condition is shown in Fig. 4. It shows the primary α structure in a background of α plus δ, and the lead distributed at grain boundaries and as tiny black globules. The hardness of this material was 200 DPN, and tensile strength yield 20 tons, ultimate 35 tons/sq. in., elongation 1·5% on 2 in. In Fig. 5 can be seen the structure resulting from quenching this material from 865° C. in water. In the main, this comprises α plus β, with some tendency for the former to break down to α plus δ, and with globules of lead irregularly distributed. Its hardness was 200 DPN. Again, Fig. 6 shows the same specimen tempered by reheating to 640° C. for 30 mins., and cooling off slowly in the furnace. Structure is almost entirely α plus δ with the localised lead spots. It shows particularly well the tendency for the δ ingredient to spheroidise. Hardness was 145 DPN.

In the above the α plus β structure as shown in Fig. 1 was criticised as suspect, and that of α plus δ in Fig. 2 referred to as the desirable formation. One fundamental

Fig. 1.—A typical structure of a straight aluminium bronze extruded rod "as received." ×200. **Fig. 2.—Showing the structure of a hardened and tempered specimen. ×200.** **Fig. 3.—The same specimen as in Fig. 2, but shown under higher magnification. ×600.** **Fig. 4.—The structure of a leaded free cutting aluminium bronze rod "as received." ×200.** **Fig. 5.—Structure of material shown in Fig. 4 when quenched from 865° C. in water. ×200.** **Fig. 6.—The same specimen as in Fig. 5, showing the structure after tempering. ×200.**



difference between the two is the presence of planes of weakness, which promote failure by cleavage, in Fig. 1; these have been eliminated by the heat-treatment transformation shown in Fig. 2. But a further valuable feature in the latter is the distribution of α plus hard δ among primary soft α.

The plates of the leaded alloy reiterate the same facts. Fig. 4 exhibits the probable cleavage planes. In Fig. 5 these have been destroyed, but the α plus β so produced offers no outstandingly useful distribution of hard-wearing points in a softer matrix, and, moreover, is acicular in formation. Fig. 6, while exhibiting grain growth, does establish that the cleavage planes are broken up; it shows the primary α and a very uniform distribution of the hard δ constituent, which shows very positive tendency to spheroidise.

Heat-treatment of Components

Modern controlled atmosphere furnaces are recommended for the heat-treatment of aluminium-bronze components. In ordinary gas- or electrically-heated furnaces a scale is formed which, although very thin and uniform, is of a refractory nature and presents quite a problem for pickling. The hardening operation can quite well be performed in the standard rotary hearth or conveyer-type furnace. The quenching tank in this case would also provide a water seal to the exit, and the gas for the furnace atmosphere would be introduced and directioned by flue control to prevent water vapour being drawn into the furnace. Either coal gas or ammonia can be the source of atmosphere with the usual external gas plant equipment. Alternatively, hardening can be performed with batch-type electric furnaces provided with a gas curtain at the door-front. The latter type of furnace can also be used for tempering with soak and slow cooling, but more economically a belt conveyerised straight-through furnace can be adopted. Design of this, of course, must be correct, with initial cooling gradient slow and graduated to avoid any abrupt quenching effect. Generally a coal-gas plant is more economical for providing the atmosphere to this type of furnace, but ammonia can be utilised either for very small installations or for those which are large enough to warrant provision for recirculation devices.

Cleaning Heat-treated Work

Regarding the cleaning of heat-treated work, particularly that which is scaled, pickling can be resorted to. This is relatively simple if equipment provided with heating facilities is available. Sulphuric acid is the best pickle, and an average general purposes concentration is 20% by volume operated at 50° to 70° C. For light scales, dilutions down to 5% may be employed at the same temperature. 2 to 3% additions, by weight, of potassium dichromate to the sulphuric pickle are sometimes made for restoring the natural golden-bronze colour to the work, but pickling times must then be carefully controlled to a minimum to avoid deep etching.

Corrosion Resistance Compared with other Copper Alloys

By virtue of the aluminium-oxide film that forms over these bronzes, they offer very good resistance to corrosion, as well as retaining their own beauty of appearance under many conditions of exposure. The following notes are of interest in so far as they give a comparison of a range of copper-rich alloys under differing conditions of corrosive attack. The range of alloys tested included:

(a) Aluminium-bronzes, nominal 10% aluminium content, with or without lead additions.
(b) Brasses including white, yellow and gilding brasses (i.e., range 60 to 90% copper).
(c) Nickel silvers, nominal nickel content 12 to 20%.
(d) Cupro nickels, nominal nickel contents 15 to 45%.

Exposure tests comprised:

A. Salt spray, exposure to mist from 20% salt solution atomised with compressed air. Specimens were washed and dried once every 24 hours.
B. Intermittent tropical conditions test. Exposure to dry warmth at 60° C. for 8-hour day, cooling in moist atmosphere with condensation over-night period.
C. Open-atmosphere exposure, free to weather conditions.

Under test A, for a period of one month, the order of merit with extent of deterioration is briefly given below:

1. *Aluminium-Bronzes.*—Gradual superficial corrosion to bluish products. Extent only slight at end of period, and no pitting.
2. *Nickel Silvers.*—Gradual superficial corrosion to greenish products. Extent only slight at end of period, high-nickel content alloys closely approaching degree of resistance shown by (1); low-nickel alloys slightly pitted.
3. *Cupro Nickels.*—Gradual superficial corrosion to bluish products. Extent appreciably heavier at end of period than shown by (1). Some pitting, more marked in the low-nickel alloys.
4. *Brasses.*—Gradual superficial corrosion to greenish-blue deposits. Much more intense at end of period than (1), and exhibiting marked pitting.

Under test B, for a period of one month, the following summarises the order of merit and resulting condition:

(1) *Aluminium Bronze.*—Unaffected. *Cupro Nickels.*—Unaffected.
(2) *Nickel Silvers.*—Slight discoloration by development of yellow to brownish-yellow hue.
(3) *Brasses.*—Dulled with irregular dark-brown staining.

Under test C, for a period of three months, order of merit and deterioration was as under:

(1) *Aluminium Bronze* (and high-nickel cupro nickels, see under (2). Gradually tarnished to blackish grey; no pitting, no loose deposits.
(2) *Cupro Nickels.*—High-nickel content alloy only slightly stained but low-nickel alloy discoloured with irregular black patches
(3) *Nickel Silvers.*—Non-adherent brown film, relatively thick.
(4) *Brasses.*—Green and black corrosion products formed, irregularly adherent.

From these simple tests, and briefly presented results, it can be seen that there is a wide difference in corrosion resistance between the aluminium bronzes and the brasses, to the benefit of the former. The nickel alloys, in general, occupy an intermediate position, and only compare favourably with the aluminium bronze when nickel content is of high order. From this it follows that aluminium bronze can give good service under general exposure conditions, including those of marine or industrial atmospheres, while it is emphasised that serious consideration should be given to the adoption of this metal for many processes of chemical engineering.

Applications

From what has been said in the foregoing, it can be seen that in a properly heat-treated aluminium-bronze alloy the structure conforms to that desirable for bearings or wear-resisting surfaces, namely, the presence of a hard constituent uniformly distributed in a background of a softer one. These alloys are tough, having high-tensile and good impact strength, while hardness can be varied within limits by choice of conditions in the tempering heat-treatment. The alloy is, therefore, an excellent one for those components which have to withstand frictional wear, or combined wear and shock. Cocks, pump components, mixing devices, shafts in general exemplify the first group, and anything in the nature of a gear wheel typifies the second category. It is desirable that the attributes of this group of heat-treatable alloys should be more widely known as through their agency many problems in engineering construction can be more simply resolved.

New Air Liners

The Fairey Aviation Company has received an order from the Air Ministry for fourteen of the F.C.1 air liners now in course of construction in the company's works at Hayes, Middlesex. This particular machine has retractable tricycle undercarriage and a retractable auxiliary wing, as well as an air-conditioned cabin. The new type of wing, which has been introduced after about three years of intensive research and experiment, will allow the machine to land and take off slowly and safely, and yet will not interfere with its high cruising speed. The machines will have a range enabling them to fly non-stop to any European capital, and will have accommodation fo 30 people.

Industrial Management and Production Control

Part IX.—Improvement of Organisation and Production by Means of Modern Methods of Industrial Administration

By F. L. Meyenberg

In this article the author presents brief data on the application of the Hollerith system in improving an organisation and its production. The example chosen is from actual practice, and although actual evidence of the savings resulting from the reorganisation of the works considered is not given, the information incorporated indicates substantial savings from the use of the system.

MANY of our readers will be interested to hear more details of the investigation in the factory of iron barrels, which was mentioned as an example of the application of the Hollerith system in the preceding article.* Lack of space forbids a report at full length; but it is hoped that this extract will provide a clear survey of the course of the investigation, which covered more than two years, and especially of the results obtained by the improvement of the organisation and production.

Purpose of the Investigation

The factory had developed during 20 years from a very small start to a works with an output of about 650 barrels per day when the question arose: How can the output be increased 50%, i.e., to about 1,000 barrels per day, without considerable interruption of production and in the most economical manner?

As usual, in such workshops which have been developed slowly in the course of decades, the systematic basis of the organisation, as well as the technical layout, had been lost to a certain extent. It was decided, first, to improve as far as possible the organisation, a measure which did not require any important new investment, and then to carry out a technical modernisation, which, of course, was not possible without considerable new investment.

Improvement of Organisation

A carefully built-up piece-work system, based on extensive time studies on the one hand and the Hollerith system on the other, could be used as valuable auxiliaries; two arrangements which need no further explanation to the readers of these articles. By study of the present system of executing an order, development of clear printed forms adapted to existing working conditions, elimination of unnecessary clerical work, avoidance of complicated forms, and insertion of new controls where necessary, etc., a systematic plan of organisation was developed, which showed in graphical representation the purposes for which the 23 necessary forms had to be used in the various departments, where they originated, and which course each had to take. Only two of these forms may here be mentioned which showed special features according to the specialities of that barrel factory—i.e., the order card index and the main programme of work. Most of the other forms were used also in other parts of the iron and steel works, of which the barrel factory was only a small part.

The order card index gave a continuous survey of the state of all live orders with all necessary details, especially at the three significant positions of production—(*a*) delivery of raw material to the shops, (*b*) entry into the buffer-areas, and (*c*) delivery to the stores of finished products. More detailed processing on the order cards was omitted deliberately in order to simplify the clerical work. Also, the programme of the work was laid down only on broad lines, leaving a certain flexibility, and therefore allowing for small breakdowns of the plant and for inserting any urgent orders which needed preference. This programme was sub-divided according to the individual sections of the factory, and each foreman received his instructions before the meeting, which was held by the works manager almost daily for discussing the state of affairs.

* METALLURGIA, June 1939.

Practical Calculation of the Measures of Organisation for Production Control

Of all possible extracts carried out by means of the Hollerith machines, and used for various purposes, such as determination of wages or of costs, and control of production, only those for the last purpose need be mentioned. They were arranged (*a*) according to the various kinds of barrel, and for each kind according to the various operations or sections, and (*b*) according to these operations or sections, and for each section according to the different grades of wages—piece work and day work.

The following controls were derived from extracts:

(*a*).
1. The various operations as percentages of the total work, especially, touching-up work in percentage of production work.
2. Checking the figures given by the piece-workers for confirmation with the clock-cards.
3. Comparison of stipulated times and actual times. Deviation of these two times, in percentages.
4. Criticism of how far an operation can be carried out against piece-work prices, where it is difficult to develop these prices by accurate time studies.
5. Times in minutes per piece and wages in pfennig per piece for each kind of barrel and for each operation.

From the extracts related to this were found:

(*b*).
1. Analysis of the different kinds of wages on the various operations.
2. Comparison of earnings per hour with those of similar categories of workmen of other production departments in the works.
3. Comparison as under (*a*) 3.
4. Actual working times of the various operations, or of the total time as indicated by the clock-cards.
5. Criticism of the amount of time used for auxiliary work and touching-up work. This enumeration may be considered only as a general survey; in special cases also other statistics have been made as the works manager asked for. This can be done by the Hollerith machines with practically no increase of work and costs.

Difficulties of Introduction

This report would not be truthful if it were not mentioned that there had been various difficulties when introducing this organisation, as that will always be the case when putting into action such an elaborate system; but they could be overcome either by carefully going into details or by limiting the system to answering questions where really suitable, and treating others by other and more simple methods.

It may further be mentioned that whereas before the introduction of the new organisation six persons had been occupied with the clerical work concerned, this number had

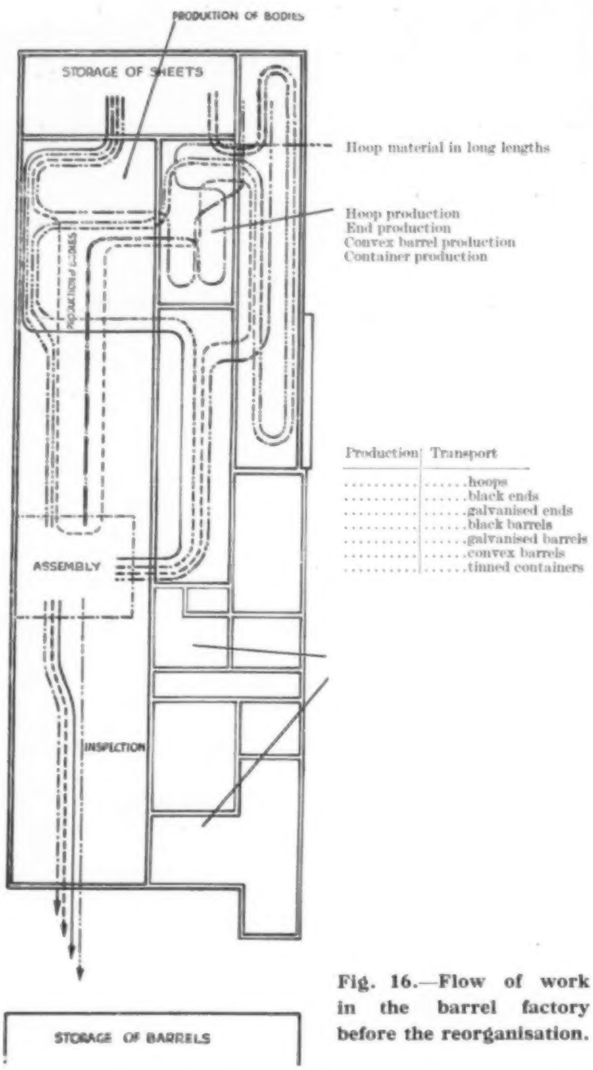


Fig. 16.—Flow of work in the barrel factory before the reorganisation.

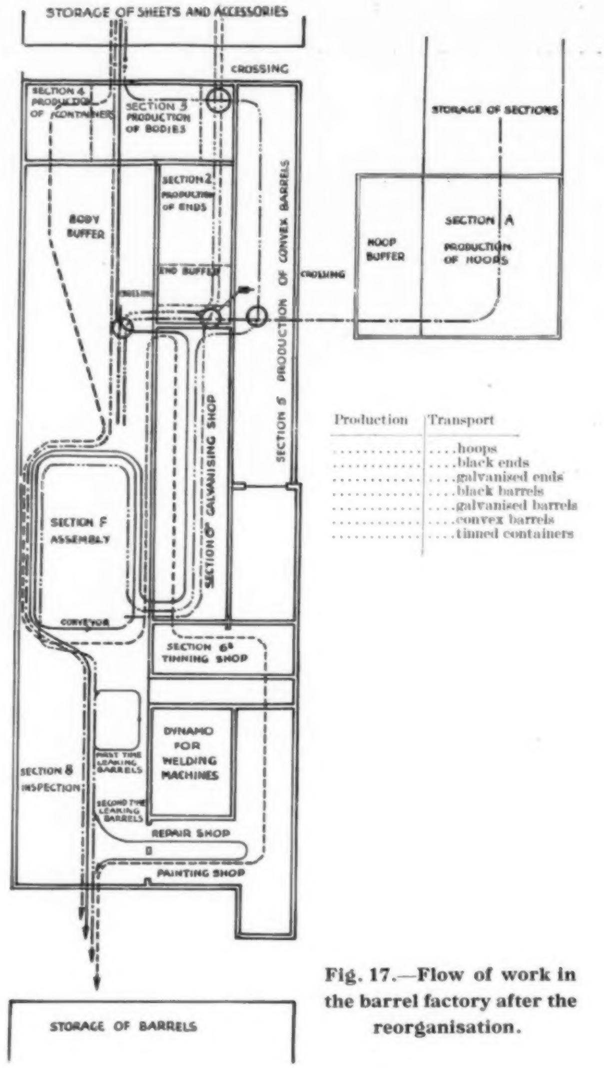


Fig. 17.—Flow of work in the barrel factory after the reorganisation.

to be increased during the introduction period to 12, and then lowered again to 8½, when the whole system had finally developed to a routine job. Sometimes this necessary increase of personnel is considered as a disadvantage of all such modern systems of organisation, and that is certainly correct if the higher costs of the increased personnel are not more than counterbalanced by savings in the actual pro-production. It should not be forgotten, as had been mentioned so often in the course of these articles, that the system of organisation is only a means to economies, it should never become the purpose itself.

The Equivalent Barrel

Finally, it may be called to the mind of the reader what has been formerly said on the use of " equivalent figures "† in this case of the equivalent barrel. This simple measure of comparison in connection with the piece-work prices in time allows especially the determination of the necessary number of workmen of the whole factory, as well as of the individual sections for various outputs. A graph has been developed from which these figures could be taken without further calculation. The comparison with the actual number of men working for special output showed how far the practical ideal, as represented by this graph, had been obtained in practice.

These hints may be sufficient to give an indication of the improvement of the organisation, although many more interesting details could be reported which would show not only the advantages of these measures, but also the difficulties which had to be overcome when introducing them. Lack of space forbids me to go deeper into these problems.

The Mechanical Improvement

After the problem of organisation had been settled so far —which, with the preparation work, took about one year,— the next step was the mechanical improvement. This can be divided into two main parts :

(*a*) The planning of the continuous flow of work ;
(*b*) The harmonising of the various sections, sub-sections, plants and machines.

(*a*) *The flow of work.* What had to be done when changing from the old layout, developed in years, sometimes in a more or less haphazard manner in order to satisfy momentary needs, to a new layout—allowing, or rather ensuring, a continuous flow of work—can best be illustrated by the two illustrations, Figs. 16 and 17. They indicate, moreover, that it was not possible to fulfil the new demands without considerable enlargement of the area. Fortunately, various adjacent shops, used for other purposes, could be removed to other parts of the works and so the necessary space could be obtained.

When considering Figs. 16 and 17 together, the final solution seems nearly obvious and the changeover rather simple ; but in practice, without undue interruption of production, this job was perhaps the most difficult part of the whole work. Sometimes intermediate steps were necessary, which had to be cancelled later, and even such drastic measures as temporary erection of walls and barriers

† Metallurgia, February 1939.

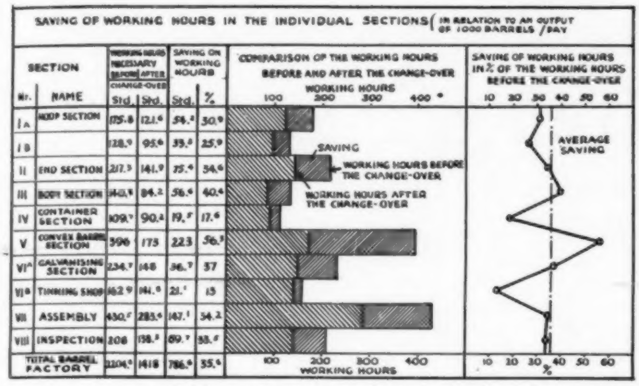


Fig. 18.—Results from the change in technique of the barrel factory, showing the saving of hours in the individual sections.

could not be avoided to enforce the planned flow of the material from one workplace to another. Special care was taken that no cross-flow of the material occurred, and where that was absolutely impossible it was at least limited to movements of the material which permitted comparatively long pauses. The planning of the work could then be arranged so that these crossing points would not be used simultaneously in different directions. It is again impossible to discuss here the interesting details.

changes of the programme as caused by urgent orders, breakdowns of machines, etc. Therefore a certain flexibility of the plant is necessary, and it is an old rule to choose the capacity of a machine or plant 20 to 25% higher than the output asked for in usual work. It is the art of the planning engineer to approach these figures equally by all individual parts of the plant; the more he succeeds in this direction the more economically the plant will work. There is then no under-capacity, or bottle-neck, which may cause stoppages of the work, but also no over-capacity, which may be the reason of unnecessarily high depreciation.

The graphical work plans of all sections, drawn up according to these principles and taking into account new machines and equipment necessary for equalising the capacities of the various workplaces, showed how the technical reorganisation should be carried out. This had also taken a period of about a year, so that the complete work could be finished in little more than two years.

The Results of the Technical Change-over

Fig. 18 illustrates the results of the technical change-over, being a summary of the individual work plans of the various sections, and does not need any further explanation. The average saving of working time of the whole factory is 35·6% of the original time. In two sections—IV, container department, and VIb, trimming shop—are the savings of time considerably below the average. Improvements could be obtained in these cases only by considerable investments, which have been intentionally omitted for the period of the investigation.

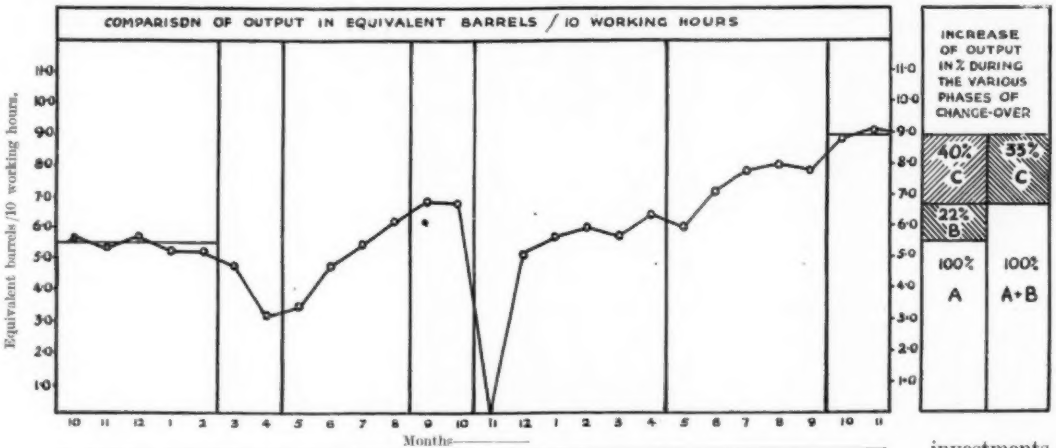


Fig. 19.—The output during the reorganisation of the factory.

A	B_1	B_2	B_3	C_1	C_2	C_3
Accurate time studies were carried out in order to fix the working conditions before the change-over.	Piece-work prices were introduced; some of the workmen were on strike.	Training of workmen, some of whom had recently been engaged.	Stable conditions were obtained after the change-over.	The technical change-over of the production; the workshops were altered; new plant and equipment installed and put into operation. During the change-over production proceeds as far as possible; it is stopped only during month 11.	The men become acquainted with the new technical equipment, small new auxiliary arrangements were introduced.	Stable conditions were obtained after the change-over.
Conditions before change-over.	The change-over of the organisation.			The technical change-over.		

The Economical Result

For obvious reasons it is not possible to publish absolute figures, also actual evidence of the savings resulting from the whole reorganisation cannot be given; but some information may be gained from the fact that, on the average, the costs of material could be lowered to 87·7%, the costs of production to 71·6%, and the total costs to 84·2% of those before the investigation, thus resulting in a saving of 15·8%. Even if only a utilisation of the plant of 60% capacity should be possible, the newly invested capital would have been saved by this 15·8% in a period of $1\frac{3}{4}$ years.

Finally, Fig. 19 may illustrate the result of the total reorganisation better than detailed explanation.

(*b*) *The harmonising work.* Careful consideration had shown that it could not be recommended to use the principle of continuous flow of work throughout the factory in its ideal form as is perhaps best known in our modern motor factories. One had to be satisfied by getting as near as possible to this ideal. In order to find the flaw, plans of the flow of work for each section were developed, determining for each operation on an individual part the present capacity of the plant, the capacity necessary for the stipulated output and the capacity proposed for the plant after the change over. The two latter figures differ generally, as practical working conditions ask for a certain assurance that the aim characterised by the programme of work can be obtained without difficulty. Never, even in the best organised works, is it possible to avoid completely sudden

The Chinese Government has recently placed orders with British firms for about £180,000 worth of constructional material. It is intended for the new railway from Kumming, capital of Yunnan, to Burma, the building of which is now being pressed on with great energy.

Standardised Aluminium Alloys in the United States

By Robert J. Anderson, D.Sc.

In most countries which manufacture aluminium and its alloys the question of standardisation has become increasingly difficult because of the rapid development and increase in numbers of the alloys available, but some form of standardisation is essential, not only to assure control in processing operations but also as a check on quality and performance in service. Considerable success in the standardisation of these alloys has been achieved in the United States of America, as this and the previous part of this article on the subject indicates.

PRODUCTS made by the Aluminium Company of America are identified by the word "Alcoa." As is well known, this large concern is the sole producer of primary aluminium in the United States. Also, it is engaged in all branches of the working-up industry, manufacturing aluminium and its alloys into every commercial form. Many alloys have been developed by the Company in order to fulfil its own requirements and those of various consuming industries.

In two instructive publications,* recently issued by the Aluminium Company of America, there is given much information concerning its standardised alloys. The compositions employed in the company's practice are presented together with properties of alloy manufactures produced by different methods, the range of sizes regularly made, and recommendations as to proper applications. Data of Alcoa alloys given here are taken from these publications.

TABLE I.
Approximate Compositions of Alcoa Aluminium Alloys for Sand Castings.

Alloy Symbol.	Alloying Elements, % (*a*).						
	Cu.	Fe.	Si.	Zn.	Mg.	Ni.	Mn.
12	8·0	—	—	—	—	—	—
43	—	—	5·0	—	—	—	—
47	—	—	12·5	—	—	—	—
108	4·0	—	3·0	—	—	—	—
109	12·0	—	—	—	—	—	—
112	7·5	1·2	—	2·0	—	—	—
122	10·0	1·2	—	—	0·2	—	—
142	4·0	—	—	—	1·5	2·0	—
195	4·0	—	—	—	—	—	—
212	8·0	1·0	1·2	—	—	—	—
214	—	—	—	—	3·8	—	—
216	—	—	—	—	6·0	—	—
220	—	—	—	—	10·0	—	—
A334	3·0	—	4·0	—	0·3	—	—
355	1·3	—	5·0	—	0·5	—	—
A355	1·4	—	5·0	—	0·5	0·8	0·8
356	—	—	7·0	—	0·3	—	—
645	2·5	1·5	—	11·0	—	—	—

(*a*) Remainder, aluminium plus normal impurities.

Table I shows the approximate compositions of Alcoa aluminium alloys for sand castings. Some mechanical properties of these alloys, as cast or heat-treated, are given in Table II. Alcoa compositions for permanent-mould castings are shown in Table III, and for die castings in Table IV. As is understood, better tensile properties are obtained for aluminium alloys, both as cast and heat-treated, by casting in metal moulds than in sand moulds. Table V gives the nominal compositions of Alcoa aluminium alloys for the manufacture of wrought products. Some mechanical properties are shown in Table VI. Typical uses or outstanding characteristics of the most important alloys are summarised below.

Alloy 12 has been superseded in the United States by other compositions for general-purpose castings—for example, 112 and 212. Sand castings required to be pressure-tight may be made of alloy 109, or one of the aluminium-silicon alloys. For such castings of complicated design the alloy A334 is often employed. It may heat-treated. Aluminium-silicon alloys, with or without other elements, are used generally in American foundry practice. They are favoured for various castings with light and heavy sections adjoining, as well as leak-proof and corrosion-resistant parts. Alloy 43 is commonly used, especially for architectural, ornamental and marine castings. Aluminium-magnesium alloys, particularly the 214 composition, find application where maximum resistance to corrosion is required. The 214 alloy is employed for chemical plant, dairy equipment, marine parts and cast cooking utensils.

TABLE II.
Mechanical Properties of Sand Cast Aluminium Alloys. Representative Values.

Alloy Symbol.	Tensile.			Brinell Hardness 500 kg., 10 mm. Ball.	Shearing Strength, Lb. per Sq. In.	Endurance Limit, Lb. per Sq. In.(*b*)
	Yield Strength, Lb. per Sq. In.(*a*)	Ultimate Strength, Lb. per Sq. In.	Elongation in 2 in., %			
12 and 212	14,000	22,000	2·0	65	20,000	8,000
43	9,000	19,000	6·0	40	14,000	6,500
47 (*c*)	11,000	26,000	8·0	50	18,000	6,000
108	14,000	21,000	2·0	55	20,000	8,500
109	18,000	24,000	1·5	75	20,000	10,000
112	14,000	23,000	1·5	70	20,000	9,000
122–T2	20,000	25,000	1·0	75	21,000	9,500
122–T61	30,000	36,000	1·0	100	29,000	—
142	24,000	28,000	1·0	80	24,000	8,000
142–T61	32,000	37,000	0·5	100	32,000	8,000
142–T571	28,000	32,000	0·5	85	27,000	8,000
195–T4	16,000	31,000	8·5	65	24,000	6,000
195–T6	22,000	36,000	5·0	80	30,000	6,500
195–T62	31,000	40,000	2·0	95	31,000	7,000
214	12,000	25,000	9·0	50	20,000	5,500
216	15,000	27,000	6·0	60	23,000	—
220–T4	25,000	45,000	14·0	75	33,000	7,000
A334	16,000	25,000	2·0	65	24,000	8,500
355–T4	20,000	30,000	5·0	60	28,000	—
355–T6	25,000	35,000	3·5	80	30,000	—
355–T51	23,000	28,000	1·5	60	22,000	7,000
A355–T51	24,000	28,000	1·5	65	22,000	8,500
A355–T59	21,000	25,000	2·0	60	21,000	8,000
356–T4	16,000	28,000	6·0	55	22,000	—
356–T6	22,000	32,000	4·0	70	27,000	8,000
356–T51	20,000	25,000	2·0	60	18,000	6,000
645	20,000	29,000	4·0	70	22,000	7,500

(*a*) Set, 0·2%.
(*b*) R. R. Moore machine and specimen, 500 million cycles.
(*c*) Modified.
N.B.—The letter "T" designates heat-treated alloys and numbers thereafter indicate the kind of heat-treatment.

Among alloys for heat-treated sand castings, the 195 composition has been used most in American practice. Alloy 356 is preferred for parts which can not be made economically in 195 Alloy owing to difficulties of founding. Alloy 220, suitably heat-treated, affords a maximum combination of yield and tensile strength, elongation and

*Anon., "Alcoa Aluminium and Its Alloys", 1938, 112 pp.; and "Structural Aluminium Handbook, 1938, 211 pp., Aluminium Company of America, Pittsburgh.

TABLE III.
Approximate Compositions of Alcoa Aluminium Alloys for Permanent-mould Castings.

Alloy Symbol.	Alloying Elements, % (a).					
	Cu.	Fe.	Si.	Zn.	Mg.	Ni.
43	—	—	5·0	—	—	—
A108	4·5	—	5·5	—	—	—
112	7·5	1·2	—	2·0	—	—
B113	7·5	1·2	1·5	—	—	—
C113	7·5	1·2	4·0	2·0	—	—
122	10·0	1·2	—	—	0·2	—
A132	0·8	0·8	12·0	—	1·0	2·5
138	10·0	1·4	4·0	—	0·2	—
142	4·0	—	—	—	1·5	2·0
144	10·0	—	4·0	—	0·2	—
B195	4·5	—	3·0	—	—	—
D195	5·5	—	0·7	—	—	—
A214	—	—	—	2·0	3·8	—
355	1·3	—	5·0	—	0·5	—

(a) Remainder, aluminium plus normal impurities.

TABLE IV.
Nominal Compositions of Alcoa Aluminium Alloys for Die Castings.

Alloy Symbol.	Alloying Elements, % (a).		
	Cu.	Si.	Ni.
13	—	12	—
43	—	5	—
81	7	3	—
82	14	5	—
83	2	3	—
85	4	5	—
93	4	2	4

(a) Remainder, aluminium plus impurities.

TABLE V.
Nominal Compositions of Alcoa Aluminium Alloys for Wrought Products.

Alloy Symbol.	Alloying Elements, % (a).								
	Cu.	Si.	Mn.	Mg.	Zn.	Ni.	Cr.	Pb.	Bi.
3S	—	—	1·2	—	—	—	—	—	—
4S	—	—	1·2	1·0	—	—	—	—	—
11S	5·5	—	—	—	—	—	—	0·5	0·5
14S	4·4	0·8	0·8	0·4	—	—	—	—	—
17S	4·0	—	0·5	0·5	—	—	—	—	—
A17S	2·5	—	—	0·3	—	—	—	—	—
18S	4·0	—	—	0·5	—	2·0	—	—	—
24S	4·4	—	0·5	1·5	—	—	—	—	—
27S	4·5	0·8	0·8	—	—	—	—	—	—
32S	0·8	12·0	—	1·0	—	0·8	—	—	—
51S	—	1·0	—	0·6	—	—	—	—	—
A51S	—	1·0	—	0·6	—	—	0·25	—	—
52S	—	—	—	2·5	—	—	0·25	—	—
53S	—	0·7	—	1·3	—	—	0·25	—	—
56S	—	—	0·1	5·2	—	—	0·1	—	—
70S	1·0	—	0·7	0·4	10·0	—	—	—	—

(a) Remainder, aluminium plus normal impurities.

impact resistance, together with excellent machinability. Alloys 122, A132, 142, 355 and A355 retain strength and hardness relatively well at moderately elevated temperatures. Accordingly, these compositions are employed mainly for parts of internal combustion engines. They are all heat-treatable.

Alloys 122 and A132 are used mostly in permanent-mould cast pistons for automotive engines. The former, in particular, is also utilised for cylinder heads of air-cooled aircraft engines and for Diesel-engine pistons made by sand casting. A valuable property of the A132 alloy is its unusually low coefficient of thermal expansion. Alloy 142 is used chiefly for parts of aircraft engines. Alloys 355 and A355 are employed mainly for crankcases and cylinder heads of liquid-cooled aircraft engines and of Diesel engines. Alloy A108 is indicated for fairly complicated castings, and A214 for cast cooking utensils, both poured in permanent moulds. Silicon-bearing alloys are used generally for die castings.

Alcoa alloys for wrought manufactures not to be heat-treated (by solution and ageing processes) include 3S, 4S, 52S and 56S. The first is employed for ordinary sheet-metal work, cooking utensils, tanks and architectural trim. Alloy 4S has higher strength than 3S and both possess good resistance to corrosion. The former is used mainly for special sheet-metal work—for example, roof sheets of railway cars. Alcoa 52S affords a good combination of tensile properties—better than 3S or 4S. Applications of 52S are for sheet work, where relatively high strength is required, for marine purposes, and in transport equipment. Manufactures of these several alloys are produced in tempers from hard to soft. The mechanical properties of 56S are comparable with those of heat-treated alloys. It is used in the form of wire, including flattened wire.

Heat-treated alloy manufactures produced by rolling, extruding, forging, or other shaping are used for many structural purposes. Notable applications are in aircraft, buses, trucks, railway trains, heavy machinery and bridges. Among Alcoa heat-treatable alloys, the composition 17S has been most generally employed. It provides very good mechanical properties. Products of 17S are used for many structural purposes, including transportation equipment.

TABLE VI.
Mechanical Properties of Wrought Aluminium Alloys. Representative Values.

Alloy Symbol and Temper.	Tensile.			Brinell hardness, 500 kg., 10 mm. Ball.	Shearing Strength, Lb. per Sq. In.	Endurance Limit, Lb. per Sq. In.(c)
	Yield Strength, Lb. per Sq. In.(a)	Ultimate Strength, Lb. per Sq. In.	Elongation in 2 in., % (b).			
3S–O	6,000	16,000	40	28	11,000	7,000
3S–½H	18,000	21,000	16	40	14,000	9,000
3S–H	25,000	29,000	10	55	16,000	10,000
4S–O	10,000	26,000	25	45	16,000	14,000
4S–½H	27,000	34,000	12	63	18,000	15,000
4S–H	34,000	40,000	6	77	21,000	16,000
11S–T3	42,000	49,000	14	95	30,000	12,500
11S–T8	42,000	55,000	14	100	—	—
14S–T	58,000	68,000	13	130	45,000	16,000
17S–O	10,000	26,000	22	45	18,000	11,000
17S–T	37,000	60,000	22	100	36,000	15,000
17S–RT	47,000	65,000	13(d)	110	38,000	—
A17S–O	8,000	22,000	27	38	15,000	—
A17S–T	24,000	43,000	27	70	26,000	13,500
24S–O	10,000	26,000	22	42	18,000	12,000
24S–T	44,000	68,000	22	105	41,000	18,000
27S–T	50,000	65,000	11	115	39,000	13,000
51S–O	6,000	16,000	35	28	11,000	6,500
51S–W	20,000	35,000	30	64	24,000	10,500
51S–T	40,000	48,000	16	95	30,000	10,500
A51S–T	40,000	48,000	20	95	32,000	10,500
52S–O	14,000	29,000	30	45	18,000	17,000
52S–½H	29,000	37,000	14	67	21,000	19,000
52S–H	36,000	41,000	8	85	24,000	20,500
53S–O	7,000	16,000	35	26	11,000	7,500
53S–W	20,000	33,000	30	65	20,000	10,000
53S–T	33,000	39,000	20	80	24,000	11,000

(a) Set, 0·2%.
(b) Round specimen, ½-in. diameter.
(c) R. R. Moore machine and specimen, 500 million cycles.
(d) Sheet specimen, $\frac{1}{16}$-in. thick.

N.B.—The letter "S" indicates wrought alloys, and symbols thereafter the kind of treatment. "O" designates annealed material, "H" full hard, and "½H" half hard. Fully heat-treated and age-hardened material is identified by "T." A number following "T" indicates that some modification of the usual heat-treatment has been applied. "R" denotes strain hardening after heat-treatment. "W" identifies material which has not been artificially aged after solution heat-treatment.

Owing to its higher yield strength the alloy 24S has superseded 17S for aircraft construction. In particular, Alclad 24S sheet has found large use in aircraft. The alloy 51S can be worked into manufactures more readily than 17S, and also as quenched can be formed cold with more facility. While 51S has been employed for a variety of purposes, it is being supplanted by 53S. The latter possesses excellent resistance to severely corrosive conditions, and it is now used extensively in architectural, marine and general industrial applications. Alloy 27S (formerly 25S) is favoured for bridges, mine equipment and other heavy-duty structures.

The alloy most generally used for forgings is 25S (27S).

It is more easily forged than 17S. But 17S and other compositions are specified for certain kinds of forgings. The highest yield and ultimate strengths in forgings are obtained with the alloy 14S. For large and intricate forgings the composition A 51S is preferred. Architectural hardware and parts for application under some corrosive conditions are forged in 53S. Where much machining is to be done the composition 11S may be chosen. Forged pistons are made of 18S and 32S.

Free-cutting stock for tooling in automatic screw machines is supplied in the alloy 11S. It has mechanical properties similar to 17S.

Mining Plant and Equipment

MINING is responsible for heavy demands on machinery, transport facilities, insurance and power; Canada, for instance, in which the mining industry has made rapid progress in recent years, is one of the largest markets for mining machinery and appliances. In 1937 the total expenditure of the gold and base metal mines, smelters and refineries for plant, transport facilities, insurance and power, was nearly $100,000,000. Nor is this the total value of the market that arises in connection with the Canadian mining industry. It does not include coal, petroleum, asbestos or a number of other branches of non-metallic mining. Nor does it take into account the immense demand for all sort of products in the communities that have grown up around the mining industries. This market shares not only in domestic production but also in import trade.

In 1937 the total value of the direct expenditures of Canadian gold mines of the nature described is estimated by the Dominion Statistician at $40,625,300. For the same year similar expenditures by base metal mines and smelters are placed at $59,331,700; making a total of $99,957,000. The figure for the gold mines shows an increase of forty over the last survey made in 1935, while the gain for the base metal industry is 60%.

Mining machinery is of special importance to manufacturers in other countries, particularly in Great Britain, and is given special facilities under the Canadian tariff. Purchases of such machinery by the Canadian gold mining industry in 1937 were valued at $5,833,000; while similar purchases by the base metal mining industry amounted to $5,273,000. Among such purchases by the gold mines were crushing, grinding and screening machinery and parts, $1,225,000; balls and rods for grinding, $1,214,000; miscellaneous mill machinery and parts, $1,528,000; and miscellaneous mine machinery, $1,722,000. Similar purchases by base metal mines and smelters included crushing, grinding and screening machinery and parts, $894,000; balls and rods for grinding, $666,000; miscellaneous mill machinery, $751,000; miscellaneous mine machinery, $911,000; miscellaneous and smelter machinery, $1,854,000.

Imports of mining and metallurgical machinery into Canada in 1937 were valued at $6,399,000. This figure, however, covers a wider range than machinery used only for gold or base metal mining. It includes, for instance, machinery used in the coal industry and in petroleum wells. Among the more important imports in 1937 were blowers for smelting and rotary kilns, $209,800; face loading machines, $223,200; safety lamps and batteries $290,000; furnaces and converting apparatus, $551,000; rock drills and parts, $785,00; ore and rock crushers and stamp mills, $951,6000; and well drilling machinery for oil and water, $2,565,500.

Monel—Its Properties, Uses, Fabrication and Available Forms

MONEL takes its name from that of Mr. Ambrose Monell, who was president of the International Nickel Co. at the time this alloy was first produced. One very large belt of ore which the company had been mining and smelting from the Sudbury district of Ontario, Canada, was found to contain, in addition to the nickel, a relatively high percentage of copper, but the separation of the two metals was both difficult and expensive. It was decided to smelt out the two metals simultaneously and to examine the commercial merits of the alloy which resulted.

It was found to contain approximately two-thirds nickel and the balance, except for about 5% of other metals, copper. Its corrosion resistant and mechanical properties proved to be of a high order, which led to considerable investigation and to the development of the grades of Monel now available. The other metals present in the natural composition include iron, manganese, silicon, carbon and sulphur.

For casting purposes, a high silicon content (above 0.06%), is possible and two grades of silicon Monel for castings have been developed, which are responsive to heat-treatment. These are solely casting alloys, not produced in rolled or forged forms. Heat-treatable materials in the latter forms are obtained by adding up to approximately 4% aluminium, the resultant alloy being known by the name of "K" Monel—an alloy which possesses the interesting feature that the thermal hardening can be superimposed on work hardening.

The history of Monel, from its first production in 1905, is traced in an interesting and informative booklet recently issued by Henry Wiggin & Co., Ltd., of Thames House, Millbank, London, S.W. 1. In addition, very complete data is given regarding its properties; uses; detailed information on hot and cold working, annealing, machining, welding, pickling, casting and forging; and also details of the forms in which Monel is available. Copies are available on request.

Wheels and pedestals in Hadfield's toughened cast steel for collieries, mines and quarries, including wheels fitted on reeled steel axles.

Courtesy of Hadfields Ltd.

Influence of the Resiliency of the Test Machine and of the Loading Speed upon the Determination of the Yield Point for Mild Steel

By G. Welter and S. Gockowski
(Technical High School, Warsaw.)

Further work on the determination of the yield point of mild steel is discussed. The authors describe the tests and discuss the adaptation of tensile machines to required test conditions. The use of hard- and soft-sprung machines in the determination of the yield point, the method of measuring, and the statistical compilation of test results are considered. The influence of loading speed, yield velocity within the range of the yield limit, and the loading speed in the plastic range, are also considered. In the light of previous work the authors' conclusions are of interest.

FOLLOWING up the work carried out on the subject of the yield point, an endeavour was made to overcome the difficulties in the way of an unequivocal determination of the yield point, believing that an accurate understanding in connection with the yield limit, and more especially with those factors which exert a decisive influence, may prove of great interest.

Up to the present the determination of the yield point by the usual tensile machines has been attended by such difficulties and inaccuracies that these results must rightly be queried. Nor is it definitely manifest whether the so-called upper or lower yield point is to be regarded as the decisive factor for the application of the materials; although we know that appreciable objections militate against practical use of the upper yield point, since the material is then likely to be in a metastable stress condition which appears to be bound up with a number of accidental factors.[1] But success in developing an equivocal and reliable method for determining the yield point should prove of special importance not only for the usual tests of industrial materials and for acceptance tests, but also for the producer and for the designer and user.

1 F. Korber, "The Problem of the Yield Point." Intern. Congress for Test of Mater., Amsterdam. 12–17. 1927.

The object of the work under review was to ascertain, by the aid of test results, the influence of those factors which are of importance in determining the yield point, and to point out ways and means which will lead to the goal of unambiguous determination of the yield limit. To such end recent results on the adaptation of tensile machines to the modified loading and measuring equipment have been communicated. In addition, the influence of the loading speed, the yield process in the range of the yield limit, and its reaction upon the test results were investigated.

TEST PERFORMANCE AND RESULTS

(a) Adaptation of the Tensile Machine to the Requisite Test Conditions

Having regard to the consideration that the natural resilience of the tensile machine exerts a decisive influence upon the load-deformation diagram, it appeared necessary to check up the reading of existent machines under varied springing conditions as far as possible. Endeavour was made by mechanical or pneumatic means to change over the normal resilience of the machine, usually very hard, in such a way that after simple precautions the same machine could be converted into one with soft springing, without special transformation measures. This was carried out on three universal tensile machines, viz., of 5, 20 and 50 tons maximum load capacity, of hard standard springing, which display the known drop at the yield limit in the load-deformation diagram. With other machines, on the other hand, the normal resiliency is sufficiently flexible to allow their inclusion in the group of soft-sprung machines. With these machines, therefore, no alteration to the springing was needed.

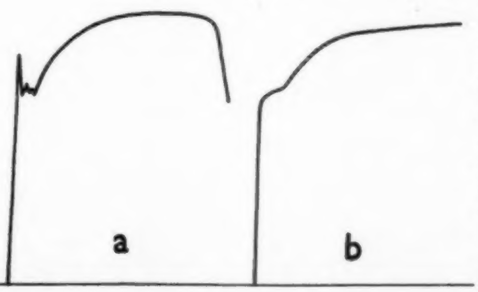


Fig. 2.—Stress-strain diagram from hard (a) and soft (b) 5-ton machine.

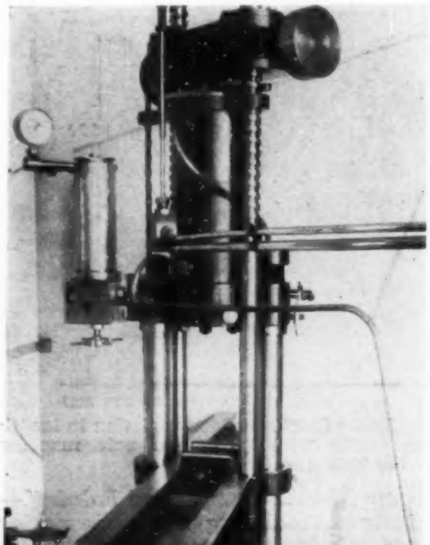


Fig. 1.—Clamping device for test bar with traction spring.

(1) *Tensile Machine for 5 tons with Mechanical Drive and Lever Dynamometer.*—The normal springing of this machine was modified appreciably by simply interposing a helical spring in the known manner. Due to this precaution the stress-elongation diagram was influenced to such fundamental extent that no upper yield point occurs with mild steel and, under a load equivalent to the lower yield limit, the material gradually begins to yield and traverses

the yield range under a gradually rising load without sudden variation in length. In order to obviate all deleterious friction between the clamping heads of the machine, a helical spring is so incorporated as to be stressed by tension and allow of being used up to a maximum load of 400 kilogs. or 700 kilogs., respectively, according to its size. In this way mild-steel pieces may be tested up to approximately 0·6 mm. diameter. In order, moreover, to avoid all eccentric loading of the test-pieces, the two clamping heads in which the pieces are seated are held axially on small balls C (Fig. 1) on universally adjustable joints. Unilateral or eccentric tensile stresses, which might have been of untoward influence upon the test results, were thus definitely and completely avoided in the test-piece by this precaution.

The helical springs, giving a springing per 100 kilogs. of approximately 15 mm. or 23 mm., respectively, convert the hard machine (with a sensitivity of 50 kilogs. drop in load against a variation of distance between clamping heads of 0·1 mm.) into a soft-sprung machine to such a degree that it will show no drop in load against a change in length of 0·1 mm., and at 0·5 mm. only a drop of a few kilogrammes.[2] Accordingly, the stress-deformation diagram only is fundamentally affected when the machine is used with and without helical springs.

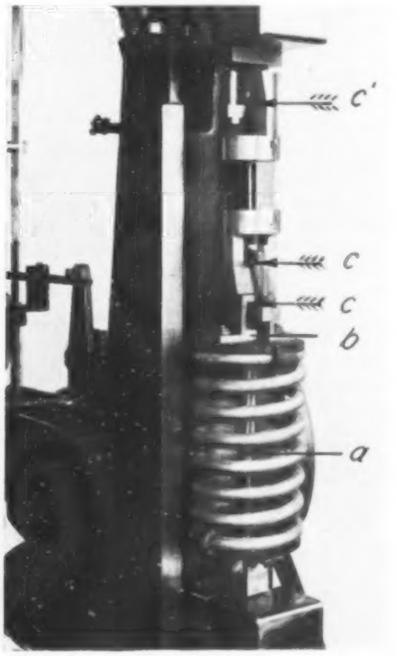


Fig. 3.—20-ton tensile machine with compression chamber for soft normal springing

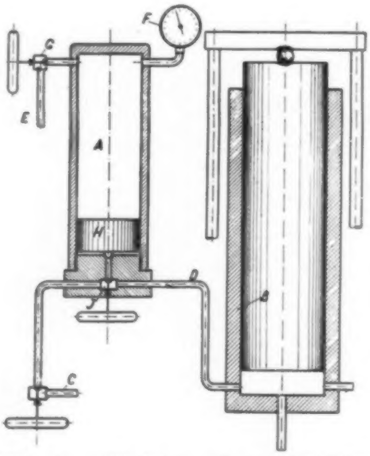


Fig. 3a.—Diagram of compression chamber and cylinder for 20-ton tensile machine.

In order to permit changing-over the machine instantly without any dismantling or converting of the clamping heads, thus without any modification, from hard to soft springing, a bolt (*a*) is provided inside the helical spring, which is retained by a nut (*b*) on the upper spring plate (Fig. 1), when the spring is put out of action. In such a case the tensile load is applied direct through the bolt, without the helical spring being operative. In this way it is possible to test a large number of pieces alternately with soft and hard machines in succession *without altering the suspension of the test bar in any way*, the same as in normal tensile testing, and to record diagrams with and without disturbances at the yield point as in Fig. 2 in any number desired (Fig. 2a, hard machine; 2b, soft machine).

(2) *Hydraulic 20-ton Tensile Machine.*—In order that the tests should not be limited to a single machine (5 tons, with mechanical drive and dynamometer), on which most of the investigations were carried out heretofore, a second tensile machine with hydraulic drive and hydraulic-pneumatic power recording was adapted in such a way that this also, a hard machine normally, could be given very soft natural springing by means of a simple manipulation (opening of a valve). This was accomplished as shown in Fig. 3 and diagram 3a by providing a pressure chamber A in addition to the pressure cylinder of the machine; this being interposed between the pressure cylinder B of the machine and the pressure pipe-line C. This pressure chamber communicated with cylinder B by the pipe D, and with a nitrogen bottle through the pipe E and a pressure gauge F. Initial pressure and gas volume in the pressure chamber A may be adjusted by the nitrogen cylinder, but the latter is shut off by the valve G in the course of working. The pressure chamber A is designed in such a way, with a float H, that it is shut off automatically on reaching a minimum oil level, so that the initial pressure shall be preserved in the container A upon breaking of the test-piece. By means of the valve J situated in the lower part of A, the latter may be shut off from the machine almost instantaneously, so that the machine will operate in the usual way with its normally hard springing.

By means of the layout described, the characteristics of this hydraulic machine also can be fundamentally changed with respect to the drop in load through variations in length between the clamping heads, as in Fig. 4. By a variation in the distance separating the clamping heads of 0·1 mm., the load on the hard 20-tons machine, such as normally used for testing, will drop, for example, from 1,000 kilogs. to approximately 760 kilogs., but by connecting up the pressure chamber such a drop in load will not occur. This hard machine may be instantly converted into one with normally soft springing by opening the valve J. The diagrams reproduced in Fig. 5 (5a, hard; 5b, soft machine) for mild steel were obtained on this machine with and without linking up the compression chamber A. In these initial stages the work was carried out on the machine within a load range up to 2½ tons. Tests with mild-steel specimens of a normal diameter up to approximately 10 mm. could be carried out on the soft-sprung machine without difficulties.

Fig. 4.—Drop in load as a function of the variation in length between clamping heads with hard and soft machine (20 tons and 50 tons).

(3) *Hydraulic 50-ton Machine by Mohr and Federhaff.*—We proceeded similarly with modifying the normal springing of a 50-ton Mohr and Federhaff machine in such a way that the known disturbances and load jumps in the yield range of steel should not occur. The machine was soft-sprung, also by the hydraulic-pneumatic principle, and successive

diagrams were recorded for the same material, with and without air cushion. The normal springing of the machine, thus fundamentally modified, may likewise be seen from Fig. 4. It should be pointed out that in view of the relatively greater friction obtaining in this machine between plunger and packing components, with a pressure fluid of low lubricating quality (water and packing cups compared with forced oil and ground plunger on the 20-tons Amsler machine), it proved necessary to impart light vibration to the cross-beam connected with the plunger of the machine by means of a small pneumatic hammer in the course of the loading process. In this way a drop in load attendant on the flexing of the test-piece was obviated. These light

zig-zag line with minor load jumps. An average of these values was determined from the various minor upper and lower yield points established towards the end of the yield range, and this probably approaches the actual value of the lower yield point most closely. In view of the numerous and multifarious developments of the yield point with hard-machine springing, it is often not a simple matter to determine the corresponding value for the individual test-pieces purely objectively.

On the other hand, it was extremely simple and easy to

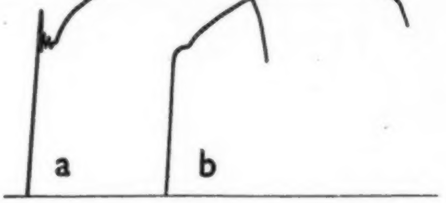


Fig. 5.—Stress-strain diagram for hard (a) and soft (b) 20-ton machine.

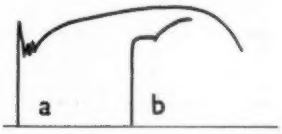
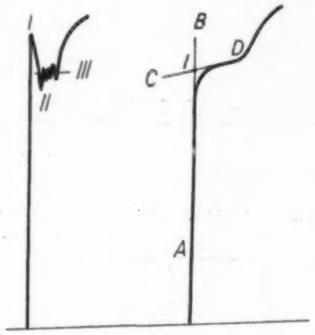


Fig. 6.—Stress-strain diagram for hard (a) and soft (b) 50-ton machine.



Figs. 7 and 8.—Diagrammatic illustration re evaluation of diagrams for hard and soft machines.

vibrations, which, however, are not transmitted to the massive vertical columns and the heavy crosshead and clamping heads of the machine upon the more remote test-piece, are sufficient to reduce the friction between plunger and packing to such extent that the yielding of the test-piece does not occur towards the side of the dynamometer, but is absorbed by the loading cylinder with pneumatic compensating vessel A. In Fig. 6a and 6b are reproduced the diagrams as recorded by the machine in normal condition (6a) and after enhancing the natural springing (6b). The work was carried out at the lowest loading stage of the machine (10 tons), the test-pieces had a diameter of approximately 8 mm.

(b) The Yield Point in Hard- and Soft-sprung Machines (Method of Measuring Same and Statistical Compilation of Test Results)

A fair number of specimens were tested on the machines described above, viz., all of the same material (mild ingot steel, 0·03% C), at various loading stages (3·5—10 mm. test-piece diameter), in two ways: on the one hand the machines were used with normal springing—that is, as employed in the usual way for determining the yield limit with a diagram record; on the other hand, the same tests were carried out with the same material, with the same machines simply changed over to soft springing. In addition, tests were carried out on two further tensile machines which, by reason of previous tests,[2] had been recognised as machines with relatively mild springing (3-ton and 4-ton Amsler machines), and this similarly in the range of the yield limit. At least two, and up to 16, test-pieces were examined at each load stage. The results of the machines with hard, normal resilience are set out in Table I, on the left, in juxtaposition to those secured on soft machines (on the right), together with characteristic course of the stress-deformation diagram in the range of the yield limit. In this way 19 tests on hard machines were compared with 32 tests of the same material obtained on soft-sprung machines with respect to their behaviour at the yield point. (Total test duration approximately 1—2 mins.)

From the diagrams obtained on hard machines, and showing severe disturbances at the yield point, three points were evaluated, as shown in Fig. 7; these were the so-called upper yield point I, the lowest point II at load-cessation, as also the mean value of the so-called lower yield point III, the course of which was frequently an irregular

2 G. Welter and S. Gockowski. *Wiadomosci Inst. Met*, 1938. No. 1, Rok 5, p. 17 METALLURGIA. No. 104, 1938, p. 61.

determine the yield range from the diagram for soft-sprung machines. As these diagrams progressed in all cases according to Fig. 8, and did not display the zig-zag disturbances of a series of upper and lower yield points, the yield limit could be determined perfectly unambiguously without any difficulty from all the tests. It was determined by the point of intersection I between the extended straight-load line A—B and the extension of the inclined yield section C—B. The slope of the distance C—D, which is contingent upon the test speed and which varies within comparatively close limits at the usual loading speeds in standard tensile tests, is of comparatively little influence upon the level of the yield limit thus determined by the point of intersection I.

It will be seen from Table I, in which the individual values are compiled, that the machine with the usual hard springing shows the known disturbances in the yield range of mild steel with distinct so-called upper and lower yield point. For the 5-ton, 20-ton and 50-ton machines, the course of the diagrams along the yield limit not only differs from one machine to another, but also from one test to another; a very divergent shaping of the zig-zag load jumps will frequently occur for like material and identical test conditions. In contra-distinction to this, under soft springing of the tensile machine a perfectly steady and undisturbed course is recorded by the machine in the yield range. This is not only the case for the machines Nos. 1a, 2a, 3a, sprung soft due to special precautions, but also for the standard laboratory machines Nos. 4 and 5, without any structural alterations (Table I).

If in this table are compared, among others, the lower yield points, determined according to Fig. 7, for the values obtained on hard-sprung machines with the single yield point of those secured on soft-sprung machines, all of which were obtained from test-pieces of varying diameter (3·5—10 mm.), it will be recognised that these values tally comparatively well. On the average, the lower yield point for mild ingot steel in the hard-sprung machine was 22·1 kilogs./sq. mm., whereas on the soft-sprung machine 22·2 kilogs./sq. mm. were determined on the average. It is evident that from a large number of individual tests the mean value determined on hard machines at the lower yield limit tallies fairly closely with the mean value measured by soft machines. This result, furthermore, also accords very well with similar tests previously carried out[2] on mild steel (0·15% C) on a hard machine (340 kilogs./sq. mm.), compared with 34·2 kilogs./sq. mm. for soft machines. With soft machines, therefore, the material begins to yield

gradually, viz., under a load corresponding to the lower yield point for hard-sprung machines. The actual yielding occurs in these cases quite gradually at slightly increasing speed, though without passing through an upper limit and without any horizontal line being recorded in the diagram suddenly and jerkily, with abrupt changes in direction, starting from the upper yield point.

On further evaluating the results obtained with respect to their maximum and minimum deviations in the two test principles, we find that according to Table II the upper yield point in hard machines fluctuates between 24·6 and 28·2 kilogs./sq. mm. On the same machine, values between 21·2 and 23·8 kilogs./sq. mm. were determined for the lower yield point. If we consider the greatest drop in load, according to point II in the diagram (Fig. 7), the divergencies amount to 18·4—23·8 kilogs./sq. mm. Between the minimum value for the lower yield point (21·2 kilogs./sq. mm.) and the maximum value for the upper yield limit (28·2 kilogs./sq. mm.) a difference of 7 kilogs./sq. mm. was thus determined in the hard machine, that is to say approximately 33%.

With soft machines, on the other hand, where the fixing of the yield point is unequivocal, a deviation among 32 individual values of only 21·4—22·9 kilogs./sq. mm. was ascertained, or only 1·5 kilog./sq. mm. (approximately 7%). Thus the yield point obtained in soft machines, and easily found, tallies very well not only with the mean value of the average value for the lower yield point in hard machines, but the deviations from these values, for an appreciable number of rest results, keep within fairly close limits.

(c) Influence of the Loading Speed

As apart from the design and springing characteristics of the tensile machine, the test-speed also is no doubt of influence on the shape and position of the yield limit for mild steel, this question also was made the subject of an informative investigation in hard and soft-sprung machines. The same material (mild ingot steel, 0·03% C) was tested on machines of hard and soft normal springing under loading and deformation velocities which varied within wide limits (ratio 1 : 14), while observing the characteristic formation of the stress deformation course along the yield limit. It is evident from Table III, in which the values are contrasted, that in hard machines the so-called upper yield point is markedly influenced by the test-speed. At the comparatively slow average test-speed of only about 0·17 mm. per sec., this value was 22·8 kilogs./sq. mm. No appreciable rise (0·5 kilogs./sq. mm.) compared with the so-called lower yield point occurred. At a speed approximately four times greater, and corresponding approximately to that frequently applied for the usual examination of series tests (test duration approximately ½ min.), the upper yield point was already found appreciably higher (25·8 kilogs.), while the lower limit remained practically unaffected (22·1 kilogs./sq. mm.). The difference between upper and lower yield point herein amounted to approximately 3·7 kilogs./sq. mm. If the testing speed be even further increased, say to about three-and-a-half or four times compared with these standard tests, we shall see that the upper yield point rises quite appreciably, and at 43·3 kilogs./sq. mm. is almost double the figure for the lower yield point. In fact, it was found far above the breaking strain, which, in this case, was determined as 33·1 kilogs./sq. mm.

The influence of the masses of the pendulum dynamometer, which already play a material role in the yield range of mild steel at the usual test speed, and which are mainly responsible for the known disturbances, is thus quite clearly made evident. Tensile diagrams for a similar test series (mild steel of 0·15% C) are reproduced in Fig. 9, starting with the high test speed (2·3 mm. per second). Under abnormally high breaking speeds the effects of the pendulum masses of hard machines may thus become so great as to lead to perfectly contradictory results (diagram No. 1). But at average speed (0·62 mm. per second), corresponding near enough to the usual testing speed, a strong influence

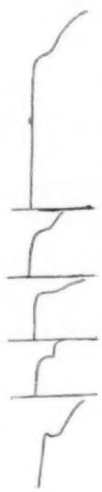
TABLE I.—INDIVIDUAL RESULTS FOR THE YIELD-POINT AS ASCERTAINED ON MACHINES WITH HARD AND SOFT SPRINGING

TYPE OF SPRINGING OF MACHINES

Hard Machine.

No.	Machine.	Yield-point Diagram.	Test-piece Diameter.	Upper Yield-point, Kg./Mm.²	Lowest Value, Kg./Mm.²	Lower Yield-point, Kg./Mm.²
1	5-ton Amsler		6	25·8 26·2 26·2 25·1	22·0 21·5 21·4 —	22·2 22·1 22·5 21·9
			4·5	25·6 24·0 24·5	— 21·8 23·2	22·1 22·2 23·7
			3·5	24·5 26·9 25·9 26·6	— — — 23·3	21·4 21·1 22·5 23·8
2	20-ton Amsler		10	26·2 28·2 25·4 26·0	21·0 — — 22·1	21·5 22·5 21·2 22·5
3	50-ton Mohr u. Federh.		10	28·0 26·8 24·8 25·5	18·4 21·0 — 20·3	21·7 21·6 21·4 21·3
Average						22·1

Soft Machine.

Yield-point, Kg./Mm.²	Test-piece Diameter.	Yield-point Diagram.	Machine.	No.
22·7 22·6	6		5-ton Amsler	1A
22·9 22·5 22·4	4·5			
1—22·2 9—21·6 2—22·7 10—22·2 3—22·4 11—22·8 4—21·2 12—22·3 5—21·8 13—22·8 6—21·8 14—22·4 7—21·8 15—21·5 8—21·7 16—21·4	3·5			
21·2 — 22·8 —	10		20-ton Amsler	2A
— 23·8* 24·3* —	8		50-ton Mohr u. Federh.	3A
21·8 21·6 22·4	6		3-ton Amsler	4
21·4 21·8	6 6		4-ton Amsler	5
21·9 22·9 21·8 22·2	10			
22·2	Average.			

DETERMINATION OF THE YIELD-POINT.

Hard Machine.

Fig. 1.

I. Upper yield.

II. Lowest value.

III. Lower yield-point.

Soft Machine.

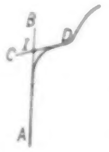


Fig. 2.

I. Yield -point.

* Tests on material with smaller bar diameter (11 mm. as against remaining 20 mm. test-bars) not used for the determination of the mean value.

is still manifest (diagram No. 2), which, in very slow working (0·0027 mm. per second), disappears almost entirely even in hard machines (diagram No. 4).

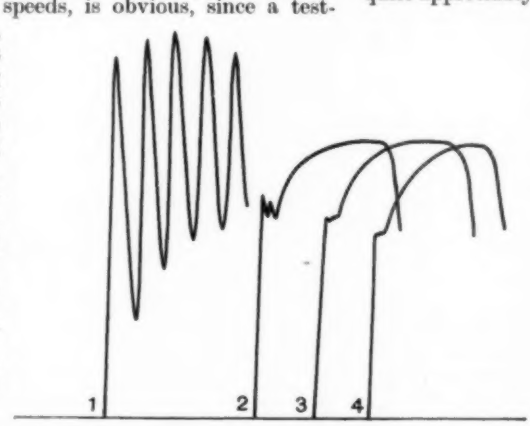
If the same tests are carried out with soft-sprung machines it will be seen that the yield limit at the low and the usual test speeds (1 : 4), Table III, is not influenced appreciably, and that individual values are obtained which may be gathered without difficulty from the diagram. The observation that this value is higher by about 1 kilog./sq. mm. at the greater deforming speed should be attributable to the existing increase in yield resistance at enhanced slip speeds. (With the hard machines this difference would not be ascertained, probably due to unreliable determination of the yield point.)

(d) Yielding Speed in the Range of the Yield Limit

Furthermore, endeavour was made to secure further data as to the yield speed in the range of the yield limit. If, as is frequently assumed, the so-called upper and lower yield points in effect indicate a surplus of energy, which is absorbed by the soft machine, the yield section must in such case be traversed at extremely high speed. The yield section, starting according to theory at the upper yield point, should be recorded jerkily, due to the large surplus of energy in extremely short time (approximately less than one-tenth second) in the diagram. But if, as has also frequently been emphasised on the basis of other works,[2] the question is one of yielding proceeding without superelevation of load, viz., starting at the lower yield point, this section will be traversed slowly in a soft-sprung machine at readily controllable speed. The fact that these speeds must be in direct relation to the type of loading, more especially at high speeds, is obvious, since a test-piece torn in less, say, than 10 seconds, must show a higher yielding speed at the yield limit than corresponds to the average elongation speed (in this case, that is, greater than approximately 2 mm. per second). But if the test is carried out appreciably more slowly—that is, at normal testing speeds, for instance, during a time of several minutes,—the yielding speed is also correspondingly retarded. It does not show, as should definitely be recorded in the event of an energy surplus, at all test speeds an extraordinarily large and, say, constant amount for these speeds, which might be of a magnitude of approximately 20 to 50 mm. per second (yield path of about 2—5 mm., which should be traversed in about one-tenth second). Also it should become evident instantaneously and jerkily under unvaried load.

By contrast, however, a speed of 0·2 to 0·3% second was ascertained in soft-sprung machines in a test duration of about 2 mins. for the distance C—D (Fig. 8), with the material under consideration (mild ingot steel 0.03% C) and this under a lightly rising load. When the test period was appreciably shortened, with soft springing, and if the machine were stopped, for example, at the beginning of yielding, so that no increase in loading could occur during the yield process, a yield velocity of this material of approximately 0·14% second was determined for a horizontal extension of the yield path. It should further be mentioned that the yield speed is undoubtedly likely to be variable, apart from the steel quality tested (Armco iron, mild or semi-mild steel), also according to the structure, grain size and arrangement of crystals, the impurities in the material, etc., in certain though comparatively minor limits. It is important, however, that in these tests, and in all investigations previously carried out, yield speeds were determined which were relatively low and did not exceed 0·1—0·33% per second. No values occurred which should be quite appreciably higher in the event of surplus energy, viz., at least by one or two orders of magnitude.

Apart from the practical test results, this circumstance also points to no energy surplus obtaining in steel in a soft-sprung machine, but that the material enters gradually into yielding without passing through any upper yield point, viz., at the lower yield limit, a process which corresponds roughly to a comparatively slow plastic deformation of the material.



V = 2·3 mm/sec. V = 0·62. V = 0·17 V = 0·0027 mm/sec.

Fig. 9.—Influence of loading speed upon the stress-strain diagram of mild steel (0.16% C).

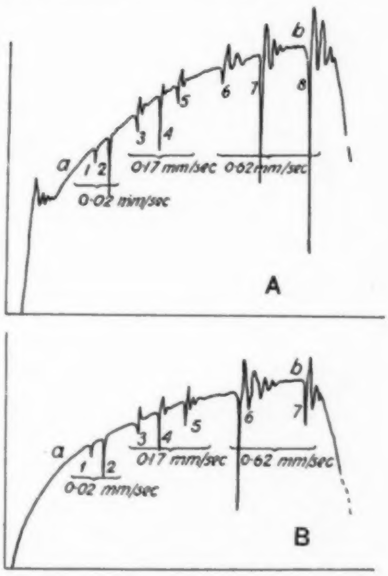


Fig. 10.—Influence of the loading speed upon the formation of the stress-strain course in interrupted test in the plastic area. A = mild ingot steel ; B = copper.

TABLE II.
FLUCTUATIONS OF THE ASCERTAINED VALUES.

Hard Machine.				Soft Machine.		
Machine.	Test-piece Diameter.	Maximum Value of the Upper Yield-point Kg./Mm.^{2}	Lowest Value, Kg./Mm.^{2}	Minimum and Maximum Values of the Yield-point, Kg./Mm.^{2}	Test-piece Diameter, Mm.	Machine
5-ton Amsler	6 4·5 3·5	26·2 24·6 26·9	21·9—21·4 22·1—21.8 21·4— —	22·6—22·7 22·4—22·9 21·2—22·8	6 4·5 3·5	5-ton Amsler
20-ton Amsler	10	28·2	21·2—21·0	21·2—22·8	10	20-ton Amsler
†50-ton Möhr Federhaff	10	28·0	21·3—18·4	23·8—24·3*	8	†50-ton Möhr Federhaff
Variations...........		28·2 24·6	23·8— — 21·2—18·4 =7 kg./mm.^{2} corresponding to about 33%	21·6—22·4	6	3-ton Amsler
				21·4—21·8 21·8—21·8	6 10	4-ton Amsler

Total deviation, 21·4—22·9.
1·5 kg./mm.^{2} corresponds to about 7%.
* Not used for determination of the mean value.
† 50-ton Möhr spring machine.

TABLE III.
TENSILE TEST MACHINE, AMSLER 5-TON.

Hard Machine.					Soft Machine.			
Test Period, Secs.	Elongation Speed, Mm./Sec.	Upper Yield-point, Kg./Mm.^{2}	Lower Yield-point, Kg./Mm.^{2}	Maximum Variation, from Diagram, Kg./Mm.^{2}	Variation Between Higher and Lower Yield-points, Kg./Mm.^{2}	Yield-point, Kg./Mm.^{2}	Elongation Speed, Mm./Sec.	Test Period Secs.
123	0·17	22·8	22·3	0·5	0·5	22·3	0·17	123
36	0·62	25·8	22·1	4·8	3·7	23·3	0·70	30
10	2·3	43·3*	—	32·8	—	—	—	—

* Breaking strain = 33·2 kg./mm.^{2}

(e) Influence of the Loading Speed in the Plastic Range

(Test broken off.)

In order to ascertain how the loading speeds act upon the formation of the stress-elongation diagrams in the plastic range of the materials, tests were carried out on a 5-ton machine, with hard, natural springing, in such a way that on exceeding the first severe deformation (yield limit) the test would be stopped. The test was continued without, or after partial, relieving and the evolution of the load-deformation diagram followed up. In Fig. 10 are reproduced the diagrams for mild steel (0·15% C, Fig. A) and soft copper (Fig. B). From diagram A it will be seen that the machine is stopped on passing the yield point, that an automatic drop in load takes place, ensuing from the variation in length (continued yielding) of the material. If the diagram is continued at low loading speed (0·02 mm. per second, slow hand drive) (Fig. A, No. 1) no super-elevation of load occurs in the diagram. After prolonged unloaded pause or test interval it is known that a super-elevation of load occurs upon renewed loading, due to ageing.[3] If the load be lowered even deeper, according to Fig. A, No 2, no super-elevation of the load will occur. The results are different, however, when applying the loading speed of 0·17 mm. per second (motor drive, low geared), as employed in standard testing practice (Fig. A, No. 3, 4 and 5). With even higher gearing (0·62 mm. per second, motor drive) the diagram sections, Nos. 6, 7 and 8, are recorded by the machine against released loadings of different magnitudes. At loading speeds corresponding to the usual principle of operation of the machines, therefore, distinctly pronounced super-elevations occur in all cases in the diagram, followed by a drop in the load. These diagram sections correspond markedly to the drop from the upper to the lower yield point when testing mild steel on hard machines (sudden transition from a purely elastic to a highly plastic deformation).

In order to eliminate the influence of the material inherent in mild steel, appropriate tests were carried out with soft copper showing no upper and lower yield limit (diagram B). Surprising to say, the result was the same. That is to say, at high loading speeds (0·17 mm. per second and 0·62 mm. per second, Nos. 3—7) super-elevations of the load would regularly occur, which should be contingent solely upon the pendulum mass and the hardness of the springing of the machine.

Tests carried out under the same conditions, but on a soft-sprung machine, showed no super-elevations of the load at the various loading speeds over the stress-elongation diagram. The diagrams showed a smooth track according to the line *a*—*b*, Figs A and B, without disturbances outside this line. The greatest loading speed applied in this case is 0·18 mm. per second, due to the springing of the machine, and could not be further increased due to structural conditions.

Conclusions

The tests have shown that it is possible without undue difficulties to develop testing machines which, contrary to the usual type of the present day, record a true and faithful reproduction of the stress-deformation course in the yield range of the materials, and more especially of mild steel. This may be achieved with machines with mechanical operation by a mechanical or hydraulic-pneumatic principle, or with hydraulic machines on a pneumatic basis. By converting a machine with hard, normal springing into one with sufficiently soft normal springing, a fundamentally different stress-elongation course will be recorded in the diagram in the yield range against the same material. The disturbances in this range, which simulate an upper and frequently even several upper and lower yield points below this level, are of such magnitude that an objective determination of the exact value for the lower yield point is frequently attended by great uncertainty. These disadvantages are obviated entirely by soft-sprung machines. A perfectly clear and straightforward diagram for evaluating the results is obtained which permits of determining the yield point, which occurs only once, in unequivocal manner and without difficulties.

In these tests special importance was attached to central loading of the test-pieces, both in the hard- and the soft-sprung machines. By interposing hardened steel balls (C, C[1], Fig. 1) in the clamping heads, provision was made for easy and reliable setting of the test bars in the tensile axis of the machine. Eccentric loading and consequential bending strains in the test-pieces were thus precluded from the outset.

Furthermore, it has again been established on the support of a series of test results, obtained in various machines, and with tests of the same material (mild ingot steel of 0·03% C) but different diameters, that the mean values, obtained on machines with soft springing, for the yield point of mild ingot steel (22·2 kilogs./sq. mm.) show a good coincidence with the lower yield limit found on hard machines, and determined from greater or lesser fluctuations (22·1 kilogs./sq. mm.). The individual values fluctuated in the former case only within minor limits, whereas with the hard machine appreciably larger fluctuations were observed in the known manner between the maximum values and the mean lower figures. Notwithstanding comparatively minor deviations of the individual values determined at the lower yield point, evaluation of the lower yield limit is tied up with appreciably uncertainty in connection with a hard machine. Due to the larger number of individual tests, in which the subjective influences are somewhat balanced in evaluation, the good coincidence between the two average figures should be explicable.

The elongation speeds determined at the yield limit provided a fresh confirmation for the argument that the hypothesis, on which the theoretical stress-elongation diagram is established for the tensile test of mild carbon steel, cannot be retained. If this assumption were correct elongation speeds should be obtained in the yield limit area, in a standard tensile test and also for appreciably slower test performance, which would correspond to an order of magnitude of more than 10 up to about 50 mm. per second. In the tests under consideration, however, elongation ve ocities were obtained which were approximately 10 to 40 times smaller. Sudden, abrupt increase in elongation (several per cent. in less than about one-tenth second) should be the result. As against this, elongation speeds were measured in the tests under review at speeds as usual in standard tensile tests (several minutes' test duration), and also with others lasting up to several hours, which were about one or two orders of magnitude smaller than the said values. The fact that under extremely rapid performance of the test, say of a few seconds total test period, the speed enforced upon the test-piece must equally react upon the elongation speed of the material, and would enhance the latter correspondingly, should be obvious and comprehensible.

In an interrupted test, irrespective of whether the material was mild steel or copper, no super-elevations occur in the load at low loading speeds (0·02 mm. per second); by contrast, at normal speeds (0·17 mm. per second) and higher ones (0·62 mm. per second) the known disturbances and super elevations of load are witnessed, which should be ascribable primarily to mass effects with hard-sprung machines.

Generally, it may be concluded from the tests results available that the drop in load at the upper yield point of mild steel is caused by the design of the tensile machine. The yield limit measured against mild steel on machines of soft normal springing is unambiguous in evaluation, and assists the designer as well as the acceptance agent by giving him a reliable value which corresponds closely to the actual properties of the material tested at the yield limit.

3 C. F. Elam, "The Influence of Rate of Deformation on the Tensile Test, with Special Reference to the Yield Point in Iron and Steel." Royal Society, London, 1938. M. J. Galibourg. *Revue de Metallurgie*, 1933, p. 36.

Internal Strains in Metals

An informal conference on the above subject was held recently at the H. H. Wills Physical Laboratory of Bristol University under the joint auspices of the Physical Society and the University of Bristol. The proceedings were divided into four sessions, covering various aspects of the subject, a report of which is given here.

A VERY successful meeting, under the joint auspices of the Physical Society and the University of Bristol. was recently held in Bristol University and constituted an informal conference on internal strains in metals. The proceedings were divided into four sessions dealing respectively with the processes of slip and gliding in metals, precipitation-hardening from supersaturated solid solutions, the effects of cold-work on structure and properties, and the relationship between internal strains and magnetism.

Glide and Hardening in Metal Single Crystals

In this paper Professor E. N. da C. Andrade stressed the remarkable increase in mechanical properties of single crystals brought about by extension, mentioning at the same time that certain other properties were hardly affected. Thus, the properties of crystals, according to the generalisation of Smekal, can be divided into two classes, namely, those that are sensitive to structural changes and those which are insensitive. Among those properties susceptible to structural changes are the deformation properties, these being influenced also by impurities and temperature. Temperature has, however, little effect upon the critical shear stress and all the available evidence suggests that at the absolute zero a crystal would not behave as an ideal lattice. In gliding under stress the direction of gliding is fundamental to the crystal, but the choice of glide planes is determined by the temperature at which the process takes place, the melting point of the metal giving the scale in each case. Slight disturbances also influence the choice of glide planes.

As regards the structural changes occurring during the process of hardening, there occurs a rotation of the crystallites in certain well-defined directions and when a single crystal is severely deformed it is found to lose its single crystal characteristics. This rotation does not occur in the glide lamellæ, but in the glide pockets between the glide lamellæ. These glide packets, which are in fact undistorted regions, are usually thicker at higher temperatures and thus are capable of exercising an appreciable influence on the degree of hardening that takes place during stressing. The different behaviour of different metals under the influence of stress can be explained on this basis.

Problems of Plastic Flow

A second paper dealing with gliding was that by Dr. E. Orowan on the above subject, in which it was mentioned that, in order to overcome certain fundamental difficulties in the interpretation of static and dynamic measurements, a specially constructed extensometer was essential. The chief problem arising in plastic flow is, according to Dr. Orowan, that of explaining the discrepancies which exist between the theoretical strength of the atomic lattice and the measured yield point. Griffiths has explained this difference by proving that in the case of glass there exist minute cracks which act as nuclei for the concentration of stress, so that the stress set up locally may be many times greater than the average strength of the material. This explanation cannot be applied to plastic gliding for when a glide has once commenced it creates the necessary conditions for a continuation of the gliding process by setting up a zone of dislocation. Also, when a glide on a single plane has started dislocations in adjacent planes are induced, and it is suggested that at the yield point of the material the propagation of these dislocations is a pure thermal activation process. The glide process is influenced by both the number of glide processes started as well as by the velocity of the dislocations, but it also is dependent upon the applied stress and the temperature, the experimental results obtained agreeing with the theoretical arguments discussed.

Age-hardening of Copper-Aluminium Alloys

In a short paper, Mr. G. D. Preston showed that in the case of 4% copper-aluminium alloy the increase in hardness which takes place at room temperature after quenching the alloy at 500°C. causes changes in the X-ray diffraction pattern. Segregation of copper atoms on the (100) planes produces well marked streaks in the diffraction pattern which grow in intensity. The hardness reaches a maximum after a few days and there is then no further change in the X-ray diffraction pattern. If the ageing be undertaken at 200°C. a large reduction in the hardness results, and some of the copper-rich plates, which are due to a segregate rich in copper, disappear. If this treatment is prolonged these streaks reappear with a simultaneous increase in hardness, and when maximum hardness is attained the copper-rich streaks break up into diffuse spots caused by thickening of the plates. Later, a second phase may be observed and this can be identified as the compound $CuAl_2$.

In addition to X-ray evidence of the existence of these plate microscopic evidence can also be secured and here again intermediate stages can be detected. Their appearance is, however, very unlike that of $CuAl_2$, for they do not possess well-defined boundaries. If to this alloy a small amount of magnesium is added age-hardening occurs by a different process in which two intermediate phases are precipitated instead of the compound $CuAl_2$, according to the evidence brought by Dr. Marie Gayler.

X-ray Evidence of Intermediate Stages during Precipitation from Solid Solutions

A further paper dealing with the formation of intermediate phases in precipitation-hardening was that given by Dr. A. J. Bradley in which the above subject was discussed. In those regions of the copper-nickel-aluminium and iron-nickel-aluminium systems which exhibit superlattice structures intermediate stages during precipitation occur. These are unstable and represent partial decomposition from supersaturated solid solutions. A single-phase structure, stable at high temperatures, thus breaks down into two phases during cooling and the decomposition takes place in two stages. Thus, in the case of copper-nickel-aluminium alloys the first stages is the formation of islands of a $CuNi_2Al$ segregate and in the iron-nickel-aluminium series this segregate is FeNiAl. Similar decomposition is also to be observed in iron-copper-nickel alloys in which the decomposition of $FeCu_4Ni_3$ provides two phases which are associated together as a laminated structure of a copper-rich phase and laminæ which are rich in iron and nickel. The precipitating phase has in each instance superlattice characteristics.

Effects of Cold-working

Several papers dealing with the effects of cold-working were presented at this conference, among them being one

by Professor W. L. Bragg on "The Structure of a Cold-Worked Metal." The existence of an amorphous layer in worked metals can be discounted, according to Professor Bragg, on account of the fact that the atoms at the centre would at once attempt to assume a regular crystalline form, as will be clear from the fact that even at the temperature of liquid air a change in atomic positions can readily occur. The lattice distortion which occurs when a metal is cold-worked has a certain energy which would be released if the metal self-annealed to form large perfect crystals, and it may be concluded from this and other evidence that the permanence of the cold-worked condition is due to the freezing-in of those thin transitional layers which are formed between one crystal and another. Professor Bragg pointed out that in the case of the gold-copper alloys four possible arrangements of the atoms in the lattice could be deduced and the behaviour of these alloys during deformation must necessarily be different from those alloys in which there are only two possible atomic arrangements within the lattice, as in the case of the copper-zinc system. It may also be shown that a shear force exists across the crystal boundaries in which the impurities are concentrated. Such boundaries can also move with the same freedom as those which are merely transitions from one crystallite to another since there must be rearrangements as well as movement in following up the boundaries. On this basis it becomes possible to explain the great effect produced by foreign atoms both on the mechanical properties of the material as well as on the rate of annealing.

Dr. W. A. Wood also discussed the mechanism of deformation in a paper entitled "Crystalline Structure and Deformation of Metals." By mechanical tests supplemented by metallographic and X-ray tests it can be shown that during deformation by cold-working the grains of a metal are dispersed into crystallites of smaller size, there being, however, a limit to which the grain size may be reduced. From Sherrer formulæ this lower limit in the grain size can be calculated and is of the order 10–4cm., but varies from metal to metal. If a second metallic constituent is present there may be a pronounced effect on the grain size, as in the case of small additions of nickel to pure copper, and in a similar way non-metallic additions to the metal are known to modify the grain size very considerably, as in the practice of bright nickel deposition.

During stressing the manner of application of the stress, and, more particularly, the rate of application of the stress, determine the response of the crystalline structure to deformation, and it is quite possible to retard the formation of dispersed crystallites and to suppress the primitive yield, although the hardness will vary independently of the external deformation. The external strain exhibited bears, however, no relation to the degree of strain-hardening occurring, and this fact raises the question as to what proportion of the overall deformation is transmitted to and is permanently held by the atomic lattice. It does not seem possible to deduce this at the moment, the evidence available not being sufficient, but as far as the actual lattice distortion is concerned it may be mentioned that after an initial contraction they may be an expansion of the lattice. The formation of entirely new grains by the removal of this superimposed distortion is the process occurring during heat-treatment, when, during low-temperature annealing, the initial softness as well as the mechanical properties may be recovered.

The question of "Lattice Distortion of Cold-Worked Metals" was again referred to in a paper by Mr. G. W. Brindley, who dealt more especially with the intensities and widths of X-ray reflection in the case of metals reduced to powder form by filing. When Duralumin is quenched from 500°C. no change in the lattice structure can be detected during three hours after quenching, but when maximum hardness has been reached after 24 hours the intensities of the X-ray reflections have decreased. Other metals exhibit a similar behaviour and several possible explanations of the cause were discussed. One very promising line of development is concerned with the changes in the average lattice parameter from one crystallite to another, although it would appear that little work has been done in this direction. The results presented by Dr. Brindley suggest that certain atomic displacements may be more or less random and the width of the displàcement may be due either to breakdown of the crystallites or to differences in lattice displacement. Thə lattice distortion thus resembles a "frozen heat motion."

Discussing "The Mechanical Effects of Intercrystalline Boundaries," Dr. Bruce Chalmers mentioned that it was difficult to assess directly the effects of boundaries only on the mechanical properties since the crystals themselves varied in properties with their size. Crystal boundaries do not, however, affect the stress-strain characteristics but the stress necessary to start slip is more particularly influenced by the proximity of a second crystal. In a face-centred cubic metal the applied stress and the orientation of the crystal are not the only factors which determine the choice of slip planes, for the orientation of adjacent grains is equally important. This being the case, there must exist across the crystal boundaries an internal force of a high order, so that the shear and tensile strengths of an intercrystalline boundary must necessarily be high also.

Internal Strains and Magnetism

During the last session of this conference, Professor Becker, in a paper under the above title, attempted to show the relationship between internal strains and coercive force. Evidence relating to internal strains, it was shown, could be obtained from magnetic measurements since nuclei of magnetism may be produced by the application of a starting field. While these nuclei do not grow in the main field the magnetizing field does not prevent the growth at the ends of the nuclei, but rather aids growth in this direction since the field energy decreases for increasing length and constant width. It is possible on this basis to develop a quantitative theory of coercive force from which a relationship between magnetic and mechanical properties can be deduced. The work is not, however, sufficiently advanced as yet to enable deductions as to the structure of the field of internal stresses to be made.

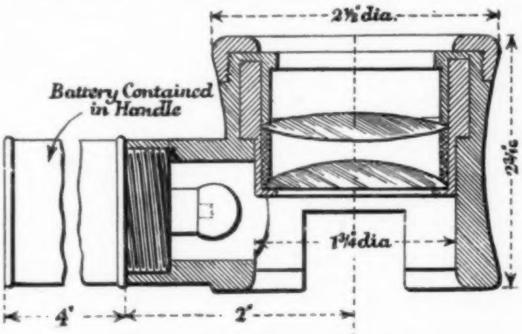
Internal Friction of Solids

This paper by Dr. C. Zener was also available for discussion in the absence of its author. According to the evidence collected, the internal friction of a solid is independent of the amplitude of the vibration used in its measurement, but increases with the temperature. In certain metals the internal friction increases rapidly at a fairly well defined temperature, this being due to the onset of slip, and the very rapid rise after recrystallization is attributable to grain growth. Thermal currents, both microscopic and macroscopic, are shown to be the fundamental cause of internal friction, which is determined very largely by the past history of the material. During annealing, damping is decreased if the annealing is undertaken just below the recrystallization temperature, and under these conditions there is little change in hardness and only a small increase in the elastic modulus. Thus, while tensile stresses are associated with large thermo-elastic effects, they are shown to be absent during torsional vibrations. Other sources of internal friction are lattice dislocations, ferromagnetism and eddy currents. Cold-working introduces distortions of the lattice and imperfections which are removed by low-temperature annealing. A change in magnetisation may also result from the application of external stress and this may be caused either by rotation of the direction of magnetism or by the movement of boundaries existing between adjacent regions.

Recent Developments in Materials, Tools and Equipment

Illuminated Magnifier

A RATHER ingenious magnifier has recently been marketed which has a wide usefulness. The device was improvised by Mr. S. W. Partington, of 96, Gloucester Road, London, S.W. 7, as an aid in his research work and it proved so useful that he subsequently patented the idea, and the instrument is now available in a very convenient form. It consists of two lenses mounted in a white bakelite circular body which constitutes a stand to rest on or over the part or object to be examined. Screwed to the bakelite body is an electric torch which is so arranged that the small bulb is placed near to the underside of the bottom lense.



Sectional view of the magnifier

The arrangement of the magnifier is shown in the accompanying illustration in which it is seen that the vital parts are accessible. The lenses are quite powerful, giving 30 dioptres, 5·57 linear magnification. They are about 1½ in. in diameter and give an area of magnification exceeding 2 in. in diameter, and this wide field of vision is one of its chief advantages. The concentration of light provided by the torch is located on the surface or object under examination and facilitates visibility.

The magnifier is not intended to be a scientific instrument but rather as a quick help in an examination of parts and objects and to save microscopic work. It can be regarded as especially useful in facilitating the inspection of metal parts. In the foundry, for instance, the large field of the lenses and the high concentration of light facilitates the examination of possible faults in castings; cracks and blemishes are readily examined in the foundry and their cause may be determined without the need for a closer laboratory inquest. Fractures can be closely inspected and useful information obtained without recourse to the more complicated examination by the microscope. It is particularly useful in examining the depth of chill in certain iron castings and in determining the structure between the chill and the metal forming the core. Since a magnicometer is included with each instrument, measurements to 256th of an inch can be made with reasonable accuracy.

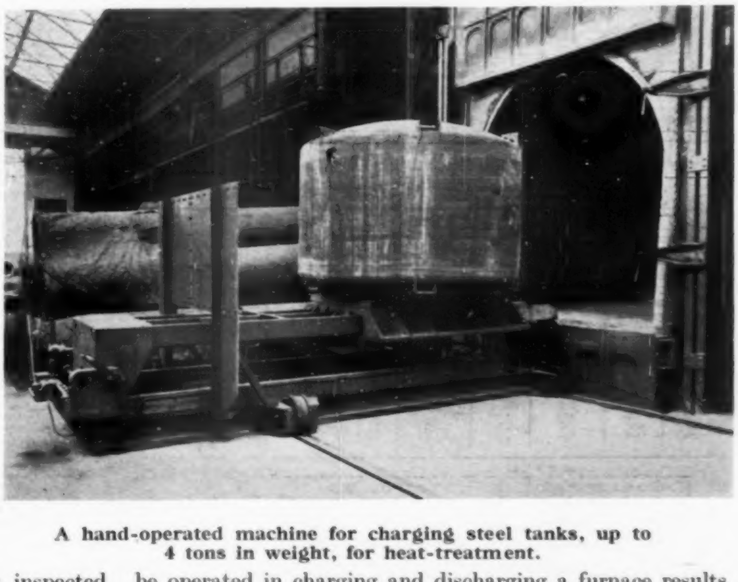
In the forging and stamping shops the instrument will be found useful in the rapid inspection of any doubtful work and since it can be readily applied by workmen there is a saving of time in coming to a decision regarding a possible fault which is only discernible with difficulty by the naked eye. In the machine shop also this instrument will be invaluable in the inspection department to facilitate the examination of incoming materials as well as the inspection of products.

This magnifier, which is obtainable at instrument shops in almost every town at 27s. 6d., is supplied with a spare battery, but both the battery and the bulb are standard and very easily obtained. We have examined and used this instrument and have no hesitation in recommending its use to facilitate the inspection of metal surfaces or fractures.

Furnace Charging Machines

THE increasing size of components and parts subjected to heat-treatment has led to the use of special charging equipment and many types of mechanical chargers are now applied to batch heat-treatment practice. The application of handling equipment of this character is primarily concerned with the elimination of manual manipulation of awkward and difficult loads and to facilitate the movement of charges in and out of a furnace; in many cases, however, the charging equipment is mounted on rails in order to simplify the transportation of the components to be heat-treated.

The type shown in the accompanying illustration is arranged for both hand and electric operation and is designed and constructed by The Incandescent Heat Co., Ltd. of Birmingham. The speed at which this machine can be operated in charging and discharging a furnace results in increased production and lowers labour costs. For many classes of work chargers of this type are now indispensable to meet the need for speedy handling of components requiring to be heat-treated.



A hand-operated machine for charging steel tanks, up to 4 tons in weight, for heat-treatment.

A New Steel Electrode

A NEW medium carbon steel electrode designed for the building up of steel parts and surfaces, known as "Hardwell 50," has recently been produced by the Lincoln Electric Co. Ltd., Welwyn Garden City, Herts., the deposit from which has considerable resistance to deformation and wear and is machinable at slow speed.

The dipped coated, which it carries, stabilises the arc and permits the deposition of a tough dense medium carbon steel.

In general, when deposited on straight carbon steel and allowed to cool naturally, the hardness of the deposit will be approximately 230 to 330 Brinell. The exact hardness will, of course, depend on the rate of cooling and the analysis of the steel on which it is deposited. The deposit may be hardened by the usual water quench from above, approximately 900° C. or by flame hardening methods.

The electrode is especially applicable to surfaces which require more resistance to deformation and wear than low carbon steel, but which must still be machinable, such as shafts, axles, collars, flanges, locomotive and tractor parts, agricultural implements, vice jaws, etc. It is also applicable for building up worn parts to size before using harder facing alloys.

In use, the electrode should be positive and the work negative; deposit wide or narrow beads as desired and it is good practice to brush each bead with a wire brush before depositing another on top of it. This new electrode can be used for vertical welding but, for best results, work should be horizontal. Where vertical welding is necessary it should be done upwards from the bottom. The rods are in two sizes $\frac{3}{16}$ in. and $\frac{1}{4}$ in. and the current range 150 to 225 and 200 to 350, respectively.

Wilco-Wiggin Resistance "Thermometal"

In many applications of thermostatic bimetal, such as temperature control and safety devices fitted to electrical domestic appliances, the bimetal strip is caused to deflect by heat transmitted from its surroundings. In the control of electric currents, however, it is often convenient to incorporate the bimetal element in the circuit, so that it is directly heated by the passage of the current. This arrangement depends, of course, on the principle that a metal having high electrical resistance becomes heated when an electric current is passed through it, the heat developed, and consequently the movement of the bimetal element, being proportional to the current passing. Electric cut-cut switches represent an interesting application of this principle, and the value of employing bimetals made to electrical resistance specifications will readily be appreciated.

Grade.	Electrical Resistance.						Deflection Constants.	
	at 70° F. (21° C.)		at 300° F. (149° C.)		at 500° F. (260° C.)		K.	D.
	Ohms per Sq. Mil. Ft.	Michroms per Cm.^{3}	Ohms per Sq. Mil. Ft.	Michroms per Cm.^{3}	Ohms per Sq. Mil. Ft.	Michroms per Cm.^{3}	Inch Units $\times 10^{-6}$	Metric Units.
R24	24	5	31	7	—	—	7·4	0·134
R39	39	8	43	9	54	11	7·2	0·130
R56	56	12	76	16	93	19	7·3	0·132
R70	70	15	93	19	111	23	7·4	0·134
R97	97	20	123	26	146	31	7·5	0·135
R118	118	25	181	38	240	51	7·3	0·132
R157	157	33	225	48	285	60	7·4	0·134
R203	203	44	273	58	335	71	7·5	0·135
R245	245	52	316	67	377	80	7·5	0·135
R310	310	66	361	77	405	86	7·5	0·135
R372	372	79	427	91	475	101	7·7	0·139
R440	440	93	488	104	519	110	7·2	0·130

Deflection constant "K" applies to the formulæ in the Wilco-Wiggin Data Book, which is free on request to Henry Wiggin and Co., Ltd.

Deflection constant "D" is the deflection in m/m. on a strip 100 m/m. long by 1 m/m. thick for a temperature rise of 1° C.

All grades of Resistance "Thermometal" have a useful deflection through a range of —50° to 600° F. (—46° to 316° C.), except R24, for which the range is —50° to 300° F (—46° to 149° C.).

The properties tabulated are for material which has been heat-treated at 650° F. (343° C.) for one hour, except R24, which has been held at 350° F. (177° C.) for one hour.

The thermal conductivity of these materials is of the same order as their electrical conductivity.

Henry Wiggin and Company Ltd., Thames House, Millbank, London, S.W. 1, have recently introduced twelve grades of Wilco-Wiggin Resistance "Thermometal" specially developed to satisfy the requirements of the electrical overload protective devices. They provide, it is claimed, a wider range of resistivity than has hitherto been available, the figures varying from as low as 5 microhms up to 93 microhms per cm³. These materials have been carefully graded according to the requirements of various designs of thermal overloads, and the temperature deflection constants are approximately the same throughout the range.

High and uniform deflection is obtained with the minimum rise in temperature, thus facilitating calibration and rendering manufacturing tolerances less critical. The good mechanical strength of this series of bimetals enables the blade to operate the tripping mechanism without undue flexing, and without overstressing the element.

Careful consideration of the particulars given in the accompanying table should help the designer of thermal overload devices to effect considerable simplification, and thereby economy, not only from reduced weight of material but also from the reduction of assembly problems.

Aluminium Inserts for Blast Furnace Cooling Boxes

A NEW type of cooling which is used in the all-welded blast furnace recently built at Bochum is described by Linicus and Sauter.* The boxes are in halves, the outer casing is of welded sheet steel and is built into the furnace brickwork wall. The cooling boxes, made of 2 mm. 99·5% aluminium sheet, fit into these steel casings. The outer narrow side of the aluminium boxes, which is reinforced by circular indentations, carries the welded-on connecting pieces for the lead in and out cooling water pipes.

The pipe through which the cooling water is supplied is carried through to the opposite side of the box so that the cold water first comes into contact with the hottest part of the box. In practice twelve of these cooling boxes are connected in series. The cross-section of the outflow pipe is constructed so that the water in the boxes is under pressure. This internal pressure pushes the comparatively thin walls of the aluminium insert into close contact with the internal surface of the outer steel casing thus ensuring good heat transmission. Some of the outer steel casings are provided in the middle with an opening which leads through into the interior of the furnace to enable temperature measurements to be made and gas samples to be taken. Such steel outer casings are fitted with two aluminium cooling boxes, one on either side of the opening.

One of the advantages of these new cooling boxes is their small height which enabled twelve rows of cooling boxes to be built into the same vertical height of stack which was formerly occupied by six rows of large cast iron cooling boxes. As a result, a much more uniform cooling of the refractory wall was obtained. The attack on the latter is, therefore, much reduced and consequently a thinner wall can be used with a corresponding reduction in cost. If the steel outer casing wears through, the aluminium cooling box can be taken out and the steel casing patched up with refractory cement. On the other hand should one of the aluminium boxes develop a leak this will be immediately noticeable as the water will run outside; the particular box can then be readily replaced. Thus, there is no danger, as in the case of the old cast-iron boxes, of water seeping through into the brickwork from a leaky box.

A further advantage is that owing to the small size of the new boxes, and the rapid flow of water through them, an accumulation of sludge is unlikely and even if it does occur the boxes can be removed and cleaned out.

These cooling boxes have given excellent results in practice. No corrosion of the unprotected aluminium has occurred but the authors point out that it might be advisable, in some cases, to treat the interior of the boxes so that they possess a protective oxide coating.

Personal

The British Thermostat Co., Ltd., announce that Mr. M. A. Jane, A.M.I.Mech.E., has been appointed to take charge of their new Birmingham office, at Essex House, 27, Temple Street, Birmingham, 2.

* W. Linicus and H. Sauter. *Aluminium.* Vol. xxi, 5, 1939, pp. 388–390.

Treating Cast Iron with Caustic Soda

A further investigation dealing with the treatment of grey cast iron with caustic soda in respect of elimination of sulphur, changes in analysis, and effect on transverse strength and microstructure is discussed.

AT the University of Minnesota, certain investigations have been carried out recently on cast iron. The results of these researches have been reviewed in METALLURGIA, the first describing a method developed for determining oxides in iron in the issue of October, 1938, and the second giving data obtained by this method indicating the amount and composition of oxides normally present in cast iron, in the issue of January, 1939. A third investigation, dealing with the treatment of grey cast iron with caustic soda in respect of elimination of sulphur, changes in chemical and oxide analysis, and effect on the transverse strength and microstructure has just been completed by T. L. Joseph, F. W. Scott and M. Tenenbaum.* A method of applying caustic soda below the surface of the metal is also dealt with.

TABLE I.

Test	NaOH lb.	Wt. of Metal Treated, lb.	NaOH %	T.C.	S1	Mn	P	S	SiO2 %
1	—	—	0	3·52	2·26	0·49	0·439	0·092	0·0145
	0·8	800	0·100	3·57	2·21	0·46	0·402	0·068	0·0222
	1·2	750	0·160	3·57	2·19	0·48	0·408	0·058	0·0077
	1·6	700	0·228	3·40	2·14	0·48	0·405	0·045	0·0054
2	—	—	0	3·52	2·31	0·47	0·420	0·107	0·0125
	0·8	800	0·100	3·46	2·20	0·44	0·409	0·077	0·0600
	1·6	750	0·201	3·48	2·13	0·44	0·405	0·052	0·0446
3	—	—	0	3·38	2·35	0·50	0·447	0·107	0·0083
	0·8	600	0·133	3·52	2·30	0·46	0·432	0·068	0·0073
	1·2	550	0·291	3·53	2·22	0·45	0·430	0·053	0·0168
	1·6	500	0·480	3·52	2·12	0·44	0·422	0·030	0·0061

Particular interest is attached to this investigation in view of the addition of alkalies to foundry iron and to other grades of pig iron which has become a rather common practice of late. More recently, interest in the use of alkali de-sulphurising agents has been stimulated by the Brassert method developed at Corby for de-sulphurising iron outside the blast furnace. In the case of foundry iron, the effect of alkali treatment on the graphite structure and the properties of the casting is of major importance, as a decrease in sulphur will affect graphitisation in the same manner as an increase in silicon, while at the same time the treatment may reduce the number of manganese sulphide-inclusions, thus producing an opposing effect by inducing supercooling and favouring the formation of fine graphite and increased combined carbon.

While foundry operators are primarily interested in obtaining metal of lower sulphur content, blast furnace operators are interested in economies of operation which appear possible through the control of sulphur outside the blast furnace. Moreover, the production of basic pig iron containing about one-half of the normal amount of silicon and 0.02% sulphur or under, is receiving considerable discussion. Since the high temperatures necessary to eliminate sulphur in the blast furnace are diametrically opposed to the production of low silicon iron, de-sulphurisation outside the blast furnace affords a possible means of producing basic iron low in both silicon and sulphur.

In the usual application of alkalies to remove sulphur, the reactions are largely confined to points of contact between the top surface of the metal bath and the reagent or alkali-bearing slag. In the present experiments fused caustic soda was added below the metallic surface and this promoted direct contact and a longer time of contact between the slag-free reagent and metal. All additions were made to one ladle, which received the metal directly from the cupola, by introducing a steel cup containing 0.4 lb. of fused caustic soda, 8 in. below the surface of the molten iron. When the reaction temperature was attained, a violent turbulence occurred, which caused a thorough distribution of the alkali. This de-sulphurising treatment was repeated until the desired amount of caustic soda was added.

The weight of the metal treated, the amount of caustic soda used, the changes in chemical analysis, and the effect on the silica content, resulting from successive additions of caustic are given in Table 1. The amount of caustic soda used is expressed both in pounds and in per cent., calculated from weight of metal treated.

The decrease of sulphur is the most marked change in the analysis of the irons and the efficacy of the caustic varies with the concentration of sulphur, decreasing with the lower sulphur concentration, a factor which is of importance to the producers of pig iron who hope to reduce the sulphur in the iron below 0.03% for use in the basic open-hearth furnace. The silica content varies somewhat with the caustic additions, a definite increase in silicates after the first addition of caustic being obtained in two tests. Further treatment and additional time appears, however,

TABLE II.

TRANSVERSE BREAKING LOAD—LB.

Test	Caustic Soda Added—% of Metal Treated.			
	Before Treatment.	0·100	0·160	0·228
1	2410	—	—	2550
	2365	2470	2430	2400
	2340	2420	2460	2660
Av.	2373	2445	2445	2537
2	—	0·100	—	0·201
		2520	—	2510
		—	—	
	2470	2600	—	2960
	2450	2780	—	2757
Av.	2460	2633	—	2757
3		0·130	0·290	0·480
	2200	2490	—	2220
	2020	2590	2380	2630
Av.	2110	2540	2380	2425

* *Metals and Alloys*, 1938, Vol. 9, No. 12, pp. 329-335.

to favour the elimination of silica. The manganese oxide was found to change radically in several cases but the ferrous oxide content showed little variation.

A series of twenty-five 1.2 by 18-in. test bars were cast in dry sand moulds to determine the changes in transverse strength, resulting from treatment with caustic soda. Several bars were broken to get representative data, and without exception the treated metal showed an appreciable increase in the transverse breaking load. The results obtained are summarised in Table 2.

This increase in strength with caustic soda additions indicates some change in the physical nature of the iron. This change might be due to some change in the chemical composition of the matrix such as an increase in combined carbon. The decrease in silicon noted would favour such a condition, but the loss of sulphur would tend to offset the effect of slightly less silicon. The effect of the removal of sulphide particles would tend to produce a supercooled structure in the iron with a corresponding increase in strength, but as the action of the alkali was not only to remove sulphur, but also to produce oxide particles, and as such oxides have a high-melting point which might act as a nuclei for graphitisation; this would offset the effect of the loss of manganese-sulphide particles.

A study of the microstructures of the various irons before and after treatment at magnifications ranging from 100 to 1,500 diameters indicated that there was a tendency for the graphite flake to become smaller in the bars to which the alkali had been added. This change was gradual and appeared to be related to the amount of caustic used. The change in the form of the graphite, however, was not great enough or sufficiently consistent with the amount of caustic added to account for a total increase of about 100% in transverse strength. A more consistent relation was found between the de-sulphurisation and the transverse strength. It was considered, although no direct evidence was obtained to support such a hypothesis, that the removal of sulphur accompanied by a corresponding increase in the ratio of manganese to sulphur would diminish any effect which the sulphide network night have om lowering the transverse strength of the iron.

Radium Industry

THE radium industry of Canada shows steady expansion. Figures as to the production of radium and uranium are not published, but the revenues of the producing company increased by more than 50 per cent. last year. The Canadian supply of radium and uranium comes from the pitchblend ores of the Great Bear Lake region, which yield radium, uranium, silver, cobalt and lead. Concentrates are produced at the mine in the North-West Territories, while the refinery operations are carried on at Port Hope in the Province of Ontario.

The sole producer of radium at present in Canada is Eldorado Gold mines Limited. The gross income of this company in 1938 is given in its annual report at $1,443,600 as compared with $903,100 in 1937. Meanwhile the operating expenditure rose from $498,100 to $884,200. During 1938 the company's mill at the mine treated 27,770 tons of ore, the highest figure in its history, and the concentrates produced had an estimated value of $1,546,000. This value covered radium, uranium and silver; and there was also a small production of cobalt concentrates. Ore shipments during the year had a value of $1,593,400, while concentrates in storage at the end of the year were valued at $411,900. The value of the concentrates produced during the first five months of the current year amounted to $1,025,000.

At the Port Hope refinery silver recovery processes are now in operation, producing silver sulphide. New processes for the processing of radio-active lead as a commercial source of radium "D" were introduced during the year. In response to market demand, production of the higher-priced black uranium oxide was doubled in 1938, compared with the year previous. The major underground development of the year at Great Bear Lake was the sinking of No. 1 shaft an additional 315 feet and the opening of new levels at 740 and 890 feet, on which development work is now proceeding, with both geological conditions and ore sections encountered at these depths being reported as satisfactory.

Radium was discovered in Canada in 1930 by Gilbert LaBine and E. C. St. Paul on the shore of Echo Bay, Great Bear Lake. Mr. LaBine is managing director of Eldorado Gold Mines Ltd. Other deposits of pitchblende have since been discovered in the same general region, particularly by Consolidated Mining and Smelting Company and by Bear Exploration and Radium Ltd., but no commercial production of radium has yet been reported from these discoveries. Production at the Port Hope refinery from the ores of Eldorado Gold Mines Ltd., consists of radium salts, yellow and orange sodium uranate, uranium oxide, uranium nitrate, silver sulphide and lead sulphate. Most of the radium produced is consigned to England for measurement and loading into needles; uranium salts are shipped principally to England and the United States; silver sulphide is consigned to the United States for final refining.

Protection of Magnesium and Magnesium Light Alloys from Corrosion

COATINGS suitable for protecting magnesium alloys against corrosion consist of a first coating of oil paint, containing either zinc or strontium chromates, and a finishing coat of nitrocellulose lacquer containing zinc oxide. Suitable pre-treatment comprises immersing the alloys for 30 to 40 minutes in a bath containing 3 grms. of ammonium sulphate, 1·5 grms. ammonium bichromate, and 1·5 grms. potassium bichromate per 100 c.cs. Alternatively, a first coat, containing 20 parts of chlorinated rubber, 15 to 20 parts bodied linseed oil, 1 part ester gum, 30 parts xylene, and 5 parts turpentine, followed by a top-coat containing 24 parts chlorinated rubber, 6 parts tricresyl phosphate, 20 parts toluene, 38 parts xylene, and 12 parts titanium white are suitable. It has been proposed to improve the adhesion and flexibility of nitrocellulose lacquer for use on magnesium alloys by incorporating silicon ester, particularly the tetræthyl compound. For this purpose N.C. is dissolved in butyl acetate and the solution diluted with toluol; to this butyl phthalate is added in the proportion of 50% of the weight of the N.C. used. To this mixture is added 85% of its weight of silicon ester.

Weight Saving in High-Speed Diesel Engines

A REDUCTION of over 30% in the specific weight, compared with any engine actually in railway service, has been achieved by the introduction by Davey, Paxman and Co., Ltd., of a 1,000 b.h.p. high-speed Diesel engine. In this engine Hiduminium RR 50 light alloy is used for the cylinder heads, which are cast in pairs for the 8-cylinder and 16-cylinder engines, and in threes for the 12-cylinder model, and also for the cylinder block and crank-case, which are combined in an integral casting. The lower part of the crank chamber is in the form of a separate light-weight sump, whilst the crankshaft bearings have caps of heat-treated Hiduminium RR 56 forgings. The hardened cams are integral with the camshaft, and drive the valves through pressure-lubricated rockers and short ball-ended Duralumin push rods. The overhead-valve gear is entirely enclosed in magnesium alloy oil-tight and dust-tight covers.

Dry-type cylinder liners of pearlitic cast iron are inserted in the cylinder block. In them run Y-alloy pistons fitted with taper-section rings. Water-cooled exhaust manifolds of Birmabright are provided. The cooling water manifolds are in the central V, and the air-induction manifolds, made of magnesium alloy, are along the outside of the cylinder-head casings.

Reviews of Current Literature

A Practical Manual of Chemical Engineering

The profession of chemical engineer is comparatively new, arising from the increasing need for ever closer collaboration between chemist, engineer and metallurgist. A practical reference work on chemical engineering should be welcomed by all concerned with the design and operation of chemical plant, and such a book has now been published by a technologist whose knowledge and experience of this subject has enabled him to compile a most informative work dealing with the practical aspects of chemical engineering.

This book represents the results of twenty years' systematic collection and testing of practical data. In its sixteen chapters it deals with materials available to the chemical engineer, their properties, uses and treatment; the design and construction of such essential equipment as pressure vessels for this industry; pipes and pipework; heat insulation; steam plant; evaporators—an exhaustive chapter on the flow of fluids, heat transfer, the vapour recompression method, and accessories for evaporators; drying; a very interesting section on adsorption; distillation; filtration; crushing and grinding equipment; and chemical works pumping.

There is an appendix detailing the legislation that affects the work of the chemical engineer in Great Britain and which deals with the safety aspect; and the 560 editorial pages are concluded with author and subject indices.

The author mentions the large-scale investigations into materials of construction and methods of assembly of high-pressure, high-temperature pipework at the Trenton Channel and Delray power-stations and quotes the results, stating that "many and varied troubles were experienced with pipe jointing, but from experience gained it was found possible to construct two joints which successfully withstood 16,000 hours at steam pressures of 1,000° F. The author states that full weld-joints appear to be the answer to the high-temperature problem."

He gives the requirements of various countries in regard to plate material for welding of pressure vessels; the many facts regarding welding which are included in this section being additional to other welding information in preceding sections of the book.

He has, of necessity, to devote ample space to details of ferrous and non-ferrous metals, and to steels and alloy steels, and cast iron and alloys. The compositions of the special structural cast irons such as Lantz, Emmel and Meehanite are given; with the interesting comment that "of recent years the development of alloy cast irons to resist shock, to withstand high stress and for corrosive conditions, has placed at the disposal of the chemical engineer a wide range of materials of great and increasing usefulness." This is logically followed by a review of the alloy cast irons; comprising the low-alloy cast irons, the white cast irons, and austenitic cast irons. The composition required to produce austenitic structure in cast iron is described, covering nickel, copper, manganese, and chromium. In dealing with the corrosion and erosion properties of the various irons, the author has included a table showing the results of corrosion tests on an austenitic cast iron compared with phosphor bronze and ordinary cast iron in 39 different corrosive media, and then comes to discussion of the high-silicon acid-resisting cast irons.

There is detailed discussion of the properties and applications of various classes of steels, comprising: plain carbon steels, low-alloy steels of the structural type, corrosion-resisting steels, and heat-resisting steels.

Following a straightforward chapter on the effect of various elements on the mechanical properties of structural steels, is a very informative section on the properties of metals at high and low temperatures. This includes much tabular matter. Throughout the book there is a wealth of illustrations and diagrams, excellently reproduced, and a point that will be appreciated by both chemical engineers or students of this subject is the inclusion of large numbers of formulæ. The formulæ apply to a great number of the many phases of this subject and add considerably to the value of a comprehensive book. It is a book that could well be regarded as a text book for students of chemical engineering and those interested in the practical aspects.

By Harold Tongue, M.I.Mech.E., Mem. A.S.M.E., A.M.I.Chem.E. Chapman and Hall Ltd., London. 36s. net.

Lead-Bronze Bearings

Last year the Deutsches Kupfer-Institut E. V. produced an informative book on the subject of lead-bronze bearings, and the German text has been closely followed in the translation of this book now published as publication No. 33 of the Copper Development Association, under the above title. There has been great interest in the development of this type of bearing but no previous attempt has been made, it is believed, to summarise the data in one volume. This book has the value of including metallurgical aspects, lubrication considerations and influences, as well as essential sections on design and manufacture of lead-bronze bearings.

It can be said that the introduction of marine Diesel engines was made possible by the use of lead-bronze shells furnished with very thin liners of whitemetal. But as the dynamic loads in these engines increased so much, particularly in aero and Diesel units, it was found that even the best whitemetals could not stand up to the loads, however good the casting process and lubrication provided. The difficulty was solved by the development of copper-lead alloys containing 28/30% lead, used as very thin liners with a steel shell support.

This very useful book contains sections on the theory of bearings, their running-in and emergency properties; antifriction properties and load capacity; strength, structure melting and casting technique, and sintered lead-bronze bearings.

It is shown that one of the two mating surfaces would possess some measure of self-lubrication and that a very satisfactory material is obtained by alloying lead with copper, since lead forms neither a solid solution nor intermetallic compounds with copper in the solid state, but exists as a separate constituent in a more or less finely divided condition, the copper providing the structural strength and the lead improving the antifriction properties.

The data tends to prove that steel-backed copper-lead bearings must be used for main and big-end bearings in aero and Diesel motor work if the load exceeds 1400–1800 lb. per sq. in., and that the maximum permissible load with steel-backed copper-lead bearings with a hardness of 30–38 is about 2600–2850 lb. per sq. in.

In regard to the structure of these alloys the book contains a most interesting paragraph, stating that "it is now generally accepted that a fine structure is superior for heavily loaded bearings, particularly those subjected to fatigue stresses as in aircraft engines. The view sometimes expressed that a fine dendritic structure is preferable to the completely spheroidal or structureless type, is not substantiated by experience. Extreme grain refinement such as is obtainable under controlled casting conditions is known to increase hardness and fatigue strength, but its effect upon antifriction properties has not yet been established. Such considerations are further complicated by the interrelationship between grain refinement, hardness and lead content."

Referring to sintered bearings, the book mentions that investigations have recently extended to the production of a porous copper material termed "copper sponge." This material is prepared by mixing coarse copper powder with a volatile non-metallic substance, followed by pressing and heating in hydrogen at 900–1000°C., when the volatile compound is driven off and the copper particles sintered

together. The "sponge" so produced is saturated in lead, by immersion in liquid lead in vacuo. The porosity can be controlled by regulating the coarseness of the copper powder and the proportion of the volatile non-metallic substance.

This book provides a useful summary of information on this subject and copies can be obtained free of charge from the C.D.A., by those of responsible status. The address is Thames House, Millbank, London, S.W.1.

Nickel Cast Iron Data Book

Much valuable information on nickel cast iron has been published and in this book the information is collected and classified and supplemented by general instructions and practical notes on the production of the different types of nickel cast iron in the foundry, including such important points as choice of raw materials, furnace operations, methods of alloying, notes on moulding practice and heat-treatment. It takes the form of a loose-leaf data book and deals with the production of nickel cast iron, its properties and applications. The object of the book is to provide, in a convenient form, data covering all aspects of the many types of nickel alloy cast iron in use to-day.

In the form now available this data book contains information under twelve sectional headings, but several additional sections are in course of preparation, some of which will deal with certain laboratory aspects, including the chemical analysis of nickel alloy cast irons and typical microstructures. In its completed form the volume will also include a series of data sheets covering recommended composition for applications in a number of specified fields.

This is a typical publication of The Mond Nickel Co. Ltd. containing valuable information and presented in a useful form. Interested readers can obtain a copy of this data book gratis on application to the Bureau of Information on Nickel, Thames House, Millbank, London, S.W. 1.

Catalogues and other Publications

The Workington Iron and Steel Co. and the Distington Iron and Steel Co., Ltd., of Cumberland, have produced a book and a pamphlet. The book details the machine-casting process, and gives figures of economies claimed and obtained by the use of Workington machine-cast pig iron, together with analyses and technical details of all grades of the Workington and Distington irons and their special "Uco" cylinder and malleable all-mine machine-cast irons. Micrographs and a large number of illustrations of these castings are included.

The pamphlet gives details of the sizes of Workington and Distington machine-cast iron slabs, with mention of their advantages and the economies possible through their use.

Both publications are available from the Publicity Department of the United Steel Companies, Ltd., 17, Westbourne Road, Sheffield, 10.

The General Electric Co., Ltd., have issued descriptions of the range of G.E.C. arc-welding plant, comprising portable lightweight a.c. sets, portable d.c. sets, and multi-operator equipment. Illustrations are provided on separate sheets. A copy of the new edition of this company's catalogue of Ironclad Switchgear has been received. This comprises chiefly non-automatic ironclad switch and fuse gear, circuit breakers, contactors, earth leakage trips, thermostats, transformers, and other control and protective equipment. The ironclad gear is now in a finish that matches the Silverlac conduit. Several new lines have been added, including all-insulated switch fuses, emergency stop buttons, and flame-proof push buttons, and a larger switch fuse transformer.

A well-illustrated brochure on valve castings made at the Penistone Works of David Brown and Sons (Hudd.), Ltd., describes the production of valves of many shapes and sizes, and the compositions of four high-frequency steels. The sections on moulding technique employed, heat-treatment practice, grain-size control, and testing and control, are clear and well presented.

The Visco Engineering Co., Ltd., Stafford Road, Croydon—a four-page folder descriptive of the operational principles of this company's pressure-type air filters for compressed air-pipe lines.

On the occasion of a recent visit of the Forfeit Feast guests of the Master and Mistress Cutler to the Atlas and Norfolk works of Messrs. Thos. Firth and John Brown, Ltd., the company produced an elaborate souvenir brochure in brown and gold. It illustrates typical basic operations of the company, showing, for instance, a 100-ton Siemens Martin furnace, part of the steel-making plant, the 6,000-ton forging press, rolling mills, and various production departments. It is concluded with page illustrations of associated companies—a very interesting compilation.

The English Steel Corporation, Ltd., have introduced a range of cemented carbide-tipped tools to cater for the machining of present-day synthetic materials and alloys at very high speeds. These are marketed under the trade name of "Escaloy," and the full range of such tools is listed in that company's catalogue of "Escaloy."

This is made in several different grades appropriate to the work upon which it will be used, and covers the requirements of steel-finish turning at high speeds and fine cuts, general work at medium to high speeds and moderate feeds, roughing on hard material, and heavy cutting at medium to high speeds with moderate feeds—cast iron and malleable iron; semi-steel; non-ferrous metals and for tipping lathe centres and milling cutters, wood-cutting tools; work guides for centreless grinders; drawing dies; bakelite; for tipping reamer blades; and for fine cuts on hard cast iron and chilled iron rolls.

The pages which list the standard shapes and prices include the useful feature of being surmounted by blue prints of the shapes and angles. (English Steel Corporation, Ltd., Openshaw, Manchester).

"Aluminium Architectural Sections"—A reference book containing a mass of data on extruded aluminium sections, and including all those sections for which an architect is likely to find a use, or which may offer him greater scope. This informative, ring bound, 76-page book is for distribution to markets outside Great Britain only, and is published by Aluminium Union Ltd., London.

A 32-page book describing the advantages of Oilite self-lubricating bearings and their applications; with ghosted drawings showing the location and function of such bearings in the components of machines is obtainable from Manganese Bronze and Brass Co., Ltd., Ipswich.

A 12-page wire-stitched, booklet descriptive of the Fraser and Chalmer's "Richards" Pulsator Jig and Pulsator Classifier—for the concentration of coarse mineral in water. (Publication F. and C. 5021.) Also a 16-page booklet dealing with Fraser and Chalmer's crushing and screening machinery for mines and quarries—an extensive range of equipment that covers all normal and many special requirements. Both publications, punched for filing, are issued by General Electric Co. Ltd., London.

Leaflet 1–1038, descriptive of the type G.1. surface hardening machine, made in three standard sizes and suitable for hardening gears from ¾ in. pitch upwards and also applicable for hardening a large variety of machine details made in carbon and alloyed steels as well as cast iron. Illustrations show the machines in operation, the operating head and the turntable pedestal. Obtainable from Shorter Process Co. Ltd., Sheffield.

A two-colour book (ref. P. 105) giving details of "Pireks" alloy steels and interesting notes on the theory and principles of heat-resisting materials. Illustrations include details of sections supplied and the book is concluded with a large data sheet with full information on the properties of ten "Pireks" alloys. It is issued by Darwins Ltd., Sheffield.

A catalogue in two colours describes "Combustioneer" stokers for coal fired furnaces by Mirrlees, Bickerton & Day, Ltd., Hazel Grove, Stockport. The principle of the mechanical stoker is to feed the coal to the fire from below, thus giving the coal a gradual heating process, driving off and using the volatile and smoke forming gases and then burning the residual coke at the top of the fire. Convenience and uniformity of control, plus economy, are the major claims made for this worm type mechanical stoker. A fan is also provided in the assembly.

Recent Russian Research on Copper Alloys

By A. Behr, B.Sc.

Some recent investigations on copper and its alloys are reviewed, attention being directed to the results of work on oxygen-free high-conductivity copper, the precipitation hardening of Kunial, the constitution and properties of copper-beryllium-nickel and copper-beryllium-aluminium alloys, the surface-hardening of copper and some of its alloys, and manganese brass intended for use as a special purpose conductor.

LIKE all other heavy industries, the Soviet copper industry has experienced, and is still undergoing, what must be considered a remarkable development in view of the various difficulties which have been encountered. About two-thirds of the copper production of the U.S.S.R. from ores is concentrated in the Ural region. Contrary to pre-war practice, comparatively lean ores of the pyrites type with copper contents of 2%, and at most 5%, are being worked up. All these ores, however, contain gold, silver and other valuable admixtures. Production of black copper from ores amounted to 32,000—33,000 (metric) tons per annum during the period 1930-1933, and rose to 83,000 tons in 1936 and to an estimated 85,000 tons in 1938. A considerable increase in production during the first quarter of 1939 over the corresponding period of last year has been reported. Production of secondary metal during the past few years is estimated at about 15,000 tons per annum.

The three main smelting works, all of which are in the Ural region, are the Kirovgrad, Krasnouralsk and Karabash works. The output of each of these in 1936 was around the 20,000-ton mark. Outputs have since been, or are being, increased. A number of smaller works are operating in the Altai region, in which a number of extensive ore deposits are situated. Development of some of these is rendered difficult owing to the semi-desert nature of the region. Production of electrolytic copper is carried out at the Molotov works near Moscow, and at the Pyshma and Kishtym works in the Urals. The last-published figures in 1935 gave the production as 40,000 tons.

Imports of copper have been rising steadily since 1935 (30,000 tons), and amounted to 65,000 tons in 1937 and to 50,000 tons during the first nine months of 1938. The total copper requirements of the country may, therefore, be estimated at 160,000 to 165,000 tons. The chief consumer (about one-third of the total) is, of course, the electrical industry, followed by the transport industry, including the aircraft and tractor industries with 20%, and general machine construction with 12%.

Research Work

As in a number of other industrial fields in the U.S.S.R., research in the copper industry has had to be concentrated to a considerable extent on the production side, and such subjects as mining, pyrites fires and their causes, flotation (including by-products) and smelting have all come in for a considerable amount of investigation. The investigations selected for review are, however, of a rather more scientific nature and may be regarded as representative. In this connection it may be mentioned that the inclusion of three researches on beryllium-containing alloys does actually reflect the interest in the U.S.S.R. in alloys—not necessarily copper-base—containing this element.

High-conductivity Copper

Some reference to original work on the production and properties of oxygen-free high-conductivity copper was made by Baranov[1] in reviewing the very scanty literature on the subject. Good results were obtained by deoxidising cathode copper melted under carbon by the addition of 0·12% of lithium or beryllium. The cast metal was sound; while the electrical conductivity of annealed wire from metal deoxidised with lithium was 59·76 m/ohm.mm.², as compared with 58·74 m/ohm.mm.² for metal deoxidised with beryllium. The ductility of the wire was good. Good electrical conductivity was also obtained by melting cathode copper under carbon in an atmosphere of carbon dioxide, the wirebars being casr in vertical moulds. The ductility of this metal, however, tended to be low owing to traces of residual copper oxide.

The precipitation hardening in Kunial, and its effect on the properties of the cold-worked alloy, formed the subject of some research by A. N. Alimov[2]. Alloys with 91·75—92·88% Cu, 6·25—5·80% Ni, and 1·25—1·05% Al were studied in the form of sheet specimens in the "as-supplied" state and after different solution/quench/precipitation heat-treatments. Some of the specimens were cold-rolled after quenching and, subsequently, subjected to precipitation heat-treatment. The work included microscopic examination and tests to determine changes in hardness, elastic properties and electrical resistance.

It was found that maximum hardness, elastic properties and conductivity were obtained in Kunial after quenching, cold-working and precipitation treatment. Maximum conductivity resulted from comparatively small—and maximum hardness and elastic properties from much larger—degrees of cold deformation. The electrical conductivity of quenched, but not cold-worked, Kunial during its subsequent ageing changes in a manner similar to that of Duralumin. Precipitation hardening was found to be considerably accelerated by cold-working after quenching and made to go to completion.

Copper-Beryllium-Nickel Alloys

The results of an investigation into the constitution and properties of copper-beryllium-nickel alloys have recently been described by Prof. Slavinskiy and his collaborators.[3] Sections of the ternary diagram parallel to the Cu-Be side with Be contents of 0·6, 0·8, 1·2, 2 and 3% and additions of nickel of 0·5, 1, 2 and 3% were studied from the point of view of the effect of nickel on the Cu-Be alloys. The ternary eutectic (α solid solution and the β-phase) in these alloys crystallised out at 860° C., while the euctectoid transformation of the β-phase commenced at between 606° and 615° C. Both thermal analysis and microscopic examination showed that additions of nickel reduced the solid solubility of beryllium in copper, the effect of the first 0·5% nickel being particularly marked. With 3% nickel the solubility was reduced to 1% at 860° C. and 0·5—0·6% at room temperature.

In both the as-cast and quenched (800° C.) alloys, the hardness increased proportionally to the amount of beryllium added. The further addition of nickel brought about an additional increase in hardness. The 3% beryllium alloy was exceptional, in so far as addition of nickel caused an appreciable drop in hardness, particularly in the quenched alloy. Experiments on the heat-treatment of the various alloys after quenching showed that, as would have been expected from the investigation of the constitution, nickel, by reducing the solid solubility of beryllium, reduced the effects of heat-treatment, which became le s

1 P. I. Baranov. *Tsvetnye Metally*. No. 1, 1939, pp. 73-83.

2 A. N. Alimov. *Metallurg*. No. 7-8, 1938, pp. 71-80.

3 M. P. Slavinskiy, N. A. Filin and L. P. Rybal'chenko. *Metallurg*. No. 11, 1938, pp. 7-16.

and less in alloys with the higher-nickel contents. In fact, the maximum hardness obtained with the nickel-containing alloys did not exceed that obtained in the binary copper-beryllium alloys—an observation similar to that of Masing and Dahl in their work on copper-beryllium alloys—with additions of tin, zinc or aluminium. The maximum effect of heat-treatment was obtained in alloys with 2 and 3% beryllium and 0·5% nickel.

Copper-Beryllium-Aluminium Alloys

Filin and Iokhel[4] have carried out an investigation of the constitution and properties of the copper-beryllium-aluminium alloys. The effect of aluminium on the copper-beryllium alloys on the one hand and the effect of beryllium on the copper-aluminium alloys on the other was studied with alloys containing 0·6, 1·5, 3·0 and 5% beryllium, with additions of 2, 4, 6, 8, 10 and 12% aluminium. Thermal and metallographic analysis enabled the authors to construct equilibrium diagrams for the alloys along the sections with constant beryllium contents, the data being subsequently incorporated into a ternary diagram, isothermal sections of which at 800° and 600° C. were also constructed.

The liquidus surface of the ternary diagram is split up into four fields corresponding, respectively, to the primary separation of the ternary α-solid solution, the β-phase on the Cu-Al side, the β^1-solid solution on the Cu-Be side, and of the α^1 phase. As the temperature falls the α-solid solution region becomes narrower, while at the same time it becomes elongated along the Cu-Al side of the diagram.

Hardness measurements on as-cast alloys and alloys annealed at, or quenched, from 800° C., showed that alloys with 0·6% beryllium and 2, 4 and 6% aluminium, being in the solid solution range, were not affected by quenching (hardness, 57—64 Brinell). Alloys with 1·5% beryllium and 2 and 4% aluminium, respectively, had a lower hardness after quenching than after annealing (77·5 and 125 Brinell, as compared with 146 and 152 Brinell, respectively).

Investigations of the change in hardness after heat-treatment were in agreement with the equilibrium diagram (no change in the hardness of the solid solution alloys with 0·6% beryllium and 2 and 4% aluminium); while the relatively largest increases were obtained by heat-treating at 300° C. The effect was particularly marked in the alloy with 1·5% beryllium and 2% aluminium, followed by alloys with 1·5 and 4, 0·6 and 10, 0·6 and 12, and 3 and 2% beryllium and aluminium, respectively. Tensile tests showed that an increase in the aluminium content, as well as an increase in the beryllium content (for a constant content of aluminium), raised both the tensile strength and elastic limit in the cast alloys, and these were further increased by heat-treatment.

Surface Hardening of Copper and some of its Alloys

The possibility of hardening the surface of copper and several of its alloys by making beryllium diffuse into the surface has been examined by Filin and Shtil'man.[5] In addition to pure copper, 8% aluminium bronze and brass (10% Zn) were used in the diffusion experiments, which were carried out at temperatures of 600°, 700° and 800° C., the specimens being packed in beryllium powder, or in some cases in a copper-15% beryllium alloy, and heated for periods of 2, 5 and 10 hours at 600°, 700° and 800° C. in a hydrogen atmosphere. As usual, it was found that the depth of the diffusion layer increased with temperature and time of heating. Diffusion at 600° C. was very slight. The maximum hardness of 201 Vickers units was obtained after heating at 800° C. for 10 hours. This corresponds to a beryllium content of 4—4·5%. This hardness could almost be doubled by quenching from 800° C. and then heat-treating at 300° C. for 3 hours.

Essentially similar results were obtained with aluminium bronze, the diffusion of beryllium into the alloy, however, being more rapid than into pure copper. On the other hand, some preliminary experiments on brass showed that diffusion of beryllium was slow, even at 800° C., owing to the volatilisation of the zinc at that temperature. Finally, it may be mentioned that tensile tests on aluminium bronze indicated that the tensile strength of the alloy was lowered by case-hardening with beryllium at 700° C., while the same treatment at 800° C. raised the tensile strength, but reduced the elongation.

Properties of Manganese Brass

The physical and mechanical properties of manganese brass intended for use as a special-purpose conductor alloy have recently been determined by Kulikov and Zakharov.[6] This alloy, which has a resistance higher than that of copper, finds application in certain electrical equipment, e.g., in synchronous motors with short-circuited rotors capable of being started directly by the application of the full mains voltage. From the production point of view, the mangansee brass is preferable to the binary and ternary aluminium bronzes. Tests on a large number of manganese brasses showed that a slight variation in the copper content (56 to 58%) had very little effect on the electrical resistance, which, at 17°—20° C., could be expressed in terms of the manganese content (Mn in %) by the following formula:

$$\rho = 0{\cdot}03725\,\text{Mn} \quad 0{\cdot}063 \frac{\text{ohm.mm.}^2}{\text{m.}}$$

For the resistance range of $0{\cdot}170$—$0{\cdot}208 \ \dfrac{\text{ohm.mm.}^2}{\text{m.}}$, i.e., $0{\cdot}189 \dfrac{\text{ohm.mm.}^2}{\text{m.}} \pm 10\%$, generally required in the applications mentioned above, the composition of the manganese brass should be Cu 56—58%, Mn 3·0—3·8%, Be 1·0—1·5%, Zn remainder.

Extruded wire of this composition has the following mechanical properties:

Limit of proportionality	16 kilog./mm.^{2}
Proof stress	20 kilog./mm.^{2}
Ultimate tensile stress	45 kilog./mm.^{2}
Elongation	30%
Reduction in area	45%

Electric Lifting Magnets for Hot Ingots

Magnets now being employed at the Cleveland Works of Dorman, Long and Co., Ltd., for handling steel ingots and billets at temperatures up to 700° C. are capable of lifting four billets, each measuring 6 ft. long and 4 in. square. The coils, with their cover, are protected from the heat by means of a special heat-diverting shield between the magnet poles. Aluminium coils, which are not affected by high temperature are employed, and the old copper coils with tape or micanite insulation between the turns have been eliminated. The whole magnet is designed in such a way that it can be immersed safely in water to cool the pole pieces when they have been in contact with the hot ingots for a considerable time.

Oxygen Cutting of Curved Surfaces

Oxygen cutting has been greatly developed during recent years, but so far the oxygen cutting machine has been confined to cutting flat areas on a horizontal plane. It is now possible, however, to cut curved pieces, obliquely or vertically, and even fixed tubing, by a machine which has a small body that adheres magnetically to the work in any position and which carries the oxygen cutting head.

This machine travels round the tube or other work at a pre-determined speed, the speed being regulated according to the depth of cut. It is driven by a universal motor. Alignment of cutting around the tube is assured by the provision of a strip steel band serving as a guide. This new development is, we understand, of French origin.

4 N. A. Filin and L. L. Iokhel'. *Metallurg.* No. 12, 1938, pp. 81–92.
5 N. A. Filin and M. L. Shtil'man. *Metallurg.* No. 12, 1938, pp. 93–98.
6 F. V. Kulikov and B. P. Zakharov. *Metallurg.* No. 3, 1939, pp. 81–86.

Business Notes and News

Output of Steel Continues on High Level

The total output of steel last month was 1,153,000 tons which exceeded by 94,000 tons the previous higher July figure in 1937. This output compared with 1,175,000 tons in June, but allowing for the usual annual stoppages at a number of steel plants, which in July occur mainly in Scotland, the daily rate of production, considering the country as a whole, advanced by approximately 1,000 tons that of June. Despite holidays and repair stoppages the industry is convinced that there is ample capacity to meet all Government demands.

There was also a further increase in the daily output of pig iron during July. Total output showed an advance to 743,000 tons which included 112,100 tons of hematite, 501,000 tons of basic, 103,800 tons of foundry and 15,700 tons of forge pig iron. This shows a marked increase on the June output which was 715,700 tons. There were 115 furnaces in blast at the end of July compared with 114 furnaces at the end of June, five furnaces having resumed operations during the month and four having ceased production.

Production of basic iron is being steadily increased to meet pressing demands of the steel works, and imports of steel scrap are also increasing, large quantities coming from the United States and the Continent.

Duffield Iron Corporation

The directors of the Duffield Iron Corporation Ltd. announce that a twin-cupola smelting furnace, which has been constructed at the company's research works at Adderbury, will be put into operation this month. This plant is primarily intended to show that the low-grade iron ore resources of Oxfordshire, at present lying dormant, are amenable to treatment by the application of the Company's method of smelting. Additionally, however, it is proposed to treat various small consignments of ore received from interests abroad as being typical of their supplies, the satisfactory smelting of which by this new plant being a condition to contracts being accepted for the sale of twin-cupola smelting plant.

Yorkshire Gas Grid

Another stage in the development of the West Yorkshire gas "grid" is an agreement between the United Kingdom Gas Corporation and the Yorkshire Coking and Chemical Co., which operates a large coking plant adjacent to the pits of Glass Houghton and Castleford Collieries and Pontefract Collieries. Financial arrangements have been made for the erection at Glass Houghton of a £32,000 gas-purifying plant, in which up to 5,000,000 cubic feet of crude gas per day can be purified.

The Glass Houghton supply will augment an output of 6,700,000 cubic feet a day from the large coking plant now nearing completion at Hemsworth pithead and bulk supplies from other pithead plants to be established in the grid area.

Aluminium Manufacture in Canada

The Aluminium Company of Canada, it is reported, intends to spend $7,000,000 between now and next May on the expansion of their plants at Arvida and Shawinigan Falls, in Quebec, and at Kingston, in Ontario. The programme will provide not only a new plant for the construction of hard alloy, but will increase the ingot capacity of the Quebec smelters by 15%, or from somewhat over 150,000,000 lb. to more than 175,000,000 lb. annually.

The work is divided into three sections. At Arvida additional smelter or pot rooms are being installed for the manufacture of aluminium. This also involves an increase in bauxite storage facilities. At Shawinigan Falls the smelter is being modernised and new pot rooms installed. Approximately half of the $7,000,000 outlay planned will be spent in Quebec, and the balance on a new plant near Kingston, Ontario.

The Kingston establishment will be equipped to manufacture plates, sheets, strip, structural shapes, rods, moulding, tubes, and other semi-finished forms of aluminium alloys. The construction of the Kingston plant is generally understood to be for the primary purpose of making hard alloys for the aircraft industry. The company expects to secure substantial orders from both Canadian and British aeroplane manufacturers.

Europe's Largest Bessemer Shop

The construction of what is claimed to be the largest Bessemer department in Europe, with a daily output capacity of 5,000 tons of steel, has been completed at the Krivoi Rog Iron and Steel Works (Ukraine). The new plant, which is shortly to be put into operation, is fully mechanised, and embodies all the latest developments in steel production. The capacity of its converters exceeds that of all the other converters in Soviet steel plants. It is a valuable addition to the Krivoi Rog Works, which has two blast furnaces of 930 cubic metres in volume and one with a volume of 1,300 cubic metres. The latter is one of three built in the U.S.S.R.—the largest blast furnaces in the world. Operating on ore from the Krivoi Rog mines, the works has the advantage of performing the complete cycle of steel production on the spot.

Barrow Hæmatite and Colvilles

An agreement has been reached between Covilles, the Scottish steel combine, and Barrow Hæmatite Steel Company for an exchange of products according to an announcement. The Barrow company have agreed to close down their steel works for a period of ten years from January next. In return Colvilles have agreed to purchase a large part of Barrow Hæmatites' output of pig iron, of which this company is one of the largest producers.

From January next Colvilles will manufacture the heavy steel products made at the Barrow works, but, in addition to making pig iron, Barrow Hæmatite will continue to operate the hoop and bar mills, and, of course, their iron ore mines.

Langley Alloys Ltd.

The manufacturing activities of High Duty Bronze, Ltd., has been taken over by Langley Alloys, Ltd. The change has been necessitated by continued increase of business. A site extending to 9½ acres has been acquired at Langley, Bucks., adjoining the main Great Western Railway line, and an entirely new foundry, with modern equipment and of a greatly increased capacity, has been put into operation. The manufacture of high-quality bronze castings, forgings and ingots, hitherto carried on by High Duty Bronze, Ltd., will be continued and extended. The company will also be in a position to supply drawn copper-alloy bars of high quality manufactured by a new and patented process.

The personnel of High Duty Bronze, Ltd., remain with the new company, and Mr. G. Skript will continue as Managing Director, the Chairman being Mr. A. A. Rowse, M.I.M.E., M.I.E.E., M.I.A.E. The new arrangements and improved facilities will enable the company to give superior service than in the past, in view of its largely extended scale of operations.

Lloyd's Register Scholarship in Marine Engineering

The Scholarship, of value £100 annually and tenable for three years at a British university, awarded by Lloyd's Register of Shipping on the results of the 1939 Studentship examination of the Institute of Marine Engineers, has been won by James Sloan, apprentice to Messrs. Harland and Wolff Ltd., Belfast, and student of Belfast College of Technology.

State Aid and British Shipping

No industry has been conducted with greater enterprise and energy that the British shipping industry, stated Lord Glanely at a recent meeting of the Tatem Steam Navigation Co., who disclaimed, on behalf of British shipowners, responsibility for the difficulties the industry has encountered. Circumstances have changed considerably in recent years and political systems now play an important part outside the control of merchant or shipowner, it is vital, therefore, that, unless the Government is prepared to risk the laying-up of the merchant marine for want of trading capital, there should be state aid.

Lord Glanely said that last year, out of rather less than 36,000,000 tons of British coal exported, less than 4,000,000 tons was carried in British vessels, and only 8% of the timber which entered the country was brought in British ships. In his view, the essential need of the industry is to take advantage of the help now being accorded by the Government so that in future a subsidy will not be wanted. He suggested that if the industry could rid itself of handicaps and anomalies the British fleet of modern ships would turn the scale considerably in favour of British shipping and improve trading results.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£95	0	0

ANTIMONY.

English		£71	0	0
Chinese		53	0	0
Crude		41	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11¾
Brazed Tubes	,,	0	1	1¾
Rods Drawn	,,	0	0	9½
Wire	,,	0	0	8¾
*Extruded Brass Bars	,,	0	0	5

COPPER.

Standard Cash		£44	5	0
Electrolytic		50	0	0
Best Selected		48	10	0
Tough		48	0	0
Sheets		81	0	0
Wire Bars		51	0	0
Ingot Bars		51	0	0
Solid Drawn Tubes	lb.	0	1	1
Brazed Tubes	,,	0	1	1

FERRO ALLOYS.

‡Tungsten Metal ° Powder, nominal	lb.	£0	4	5¼
‡Ferro Tungsten ° nominal	,,	0	4	4
Ferro Molybdenum ° ,,		0	4	10
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL				
2–4% Carbon, scale 12/– per unit	ton	34	15	0
4–6% Carbon, scale 8/– per unit	,,	24	5	0
6–8 Carbon, scale 7/6 per unit	,,	23	15	0
8–10% Carbon, scale 7/6 per unit	,,	23	15	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
†Metallic Chromium	,,	0	2	6
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	9	2	6
20/30% basis 25%, scale 3/6 per unit	,,	10	17	6
45/50% basis 45%, scale 5/- per unit	,,	12	10	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn, basis 65% Mn	,,	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	7

FUELS.

Foundry Coke—		
S. Wales	£1 18 0	/£2 1 6
Scotland	£1 10 0	/£1 15 0
Durham	—	1 14 6
Furnace Coke—		
Scotland	£1 5 0	/£1 7 6
S. Wales	—	1 7 6
Durham	—	1 4 2

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£68	0	0
*Commercial Ingots		48	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—			
Crown Bars	£12	5	0
N.E. Coast—			
Rivets	—		
Best Bars	12	15	0
Crown Bars	12	5	0
Lancashire—			
Crown Bars	12	5	0
Hoops	13	12	6
Midlands—			
Crown Bars	12	5	0
Marked Bars	15	5	0
Unmarked Bars	—		
Nut and Bolt Bars	11	0	0
Gas Strip	13	12	6
S. Yorks.—			
Best Bars	12	5	0
Hoops	13	12	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	11¾
†Sheet to 10 W.G.	,,	0	1	0¼
†Wire	,,	0	1	1⅝
†Rods	,,	0	1	2
†Tubes	,,	0	1	7
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£5	15	6
Foundry No. 1	5	3	0
,, No. 3	5	0	6
N.E. Coast—			
Hæmatite No. 1	5	15	0
Foundry No. 1	5	2	0
,, No. 3	4	19	0
,, No. 4	4	18	0
Silicon Iron	—		
Forge	4	18	0
Midlands—			
N. Staffs. Forge No. 4	5	0	0
,, Foundry No. 3	5	1	0
Northants—			
Foundry No. 1	5	1	6
Forge No. 4	4	17	6
Foundry No. 3	4	18	6
Derbyshire Forge	5	0	0
,, Foundry No. 1	5	4	0
,, Foundry No. 3	5	1	0
West Coast Hæmatite	5	15	6
East ,, ,,	5	15	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.	
Per English ton	Kr.160
Billets, single welded, over 0·45 Carbon.	
Per metric ton	Kr.335-385
Per English ton .. £17 11	3/£20 3 9
Wire Rods, over 0·45 Carbon.	
Per metric ton	Kr.375-405
Per English ton .. £19 12	2/£21 4 9
Rolled Martin Iron, basis price.	
Per metric ton	Kr.230-250
Per English ton .. £12 1	2/£13 2 2
Rolled charcoal iron, finished bars, basis price.	
Per metric ton	Kr.360
Per English ton	£18 17 6
f.o.b. Gothenburg.	

SCRAP METAL.

Copper, Clean	£36	0	0
,, Braziery	31	0	0
,, Wire	—		
Brass	21	10	0
Gun Metal	35	0	0
Zinc	8	0	0
Aluminium Cuttings	65	0	0
Lead	13	10	0
Heavy Steel—			
S. Wales	3	0	0
Scotland	2	19	0
Cleveland	3	0	0
Cast Iron—			
Midlands	2	15	0
S. Wales	3	2	0
Cleveland	3	12	6
Steel Turnings—			
Cleveland	—		
Midlands	2	0	0
Cast Iron Borings—			
Cleveland	—		
Scotland	1	14	0

SPELTER.

G.O.B. Official	—		
Hard	£10	5	0
English	16	5	0
India	14	5	0
Re-melted	14	10	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£10	10	6
North-East Coast	10	10	6
Midlands	10	10	6
Boiler Plates (Land) Scotland	11	8	0
,, ,, (Marine) ,,	—		
,, ,, (Land), N.E.Coast	11	8	0
,, ,, (Marine) ,,	—		
Angles, Scotland	10	8	0
,, North-East Coast	10	8	0
,, Midlands	10	8	0
Joists	10	8	0
Heavy Rails	9	10	0
Fishplates	13	10	0
Light Rails	9	13	6
Sheffield—			
Siemens Acid Billets	10	10	0
Hard Basic .. £8 10 0 to	10	0	0
Medium Basic, £7 12 6 to	7	17	6
Soft Basic	7	7	6
Hoops	11	15	0
Manchester Hoops	12	7	0
Scotland, Sheets 24 B.G.	14	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	0
Finished Bars 18% Tungsten	,,	0	3	10
Extras :				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to $\frac{3}{16}$ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ½ in. × ⅛ in.	,,	0	1	0

TIN.

Standard Cash	£229	15	0
English	230	0	0
Australian	—		
Eastern	230	5	0
Tin Plates I.C. 20 × 14 box	1	0	3

ZINC.

English Sheets	£29	10	0
Rods	18	15	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£15	19	0
English	18	5	0

* McKechnie Brothers, Ltd., August 14. † C. Clifford & Sons, Ltd., August 14. ‡ Murex Limited, August 14.
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§ Prices ex warehouse, August 14. ¶ The prices fluctuate with the price of Tungsten.


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METALLURGIA. *Contents.* For AUGUST, 1939.

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd. Imperial Chemical House, London, S.W. 1.

Alloys
Addalloy Metal Co. Ltd., 14, Park Lane, Sheffield 10.

Aluminium and its Alloys
Aluminium Union, Ltd., The Adelphi, Strand, London, W.C. 2.
Earle, Bourne & Co., Ltd., Heath Street South, Birmingham.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C. 2.
Priestman, T. J., Ltd., Birmingham.

Anti-Friction Metals
Addalloy Metal Ltd., 14, Park Lane, Sheffield, 10.
Earle Bourne & Co., Ltd., Birmingham.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Clifford, Chas. and Son, Ltd., Birmingham.
Earle, Bourne & Co., Ltd. Heath Street South, Birmingham.
I.C.I. Metals Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co., Ltd., Handford Works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
G.W.B. Electric Furnaces, Ltd., Belgrove House, Belgrove St., W.C. 1.
I.C.I. Cassel Cyanide.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove St., Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Rd., Middlesbrough.

Electrodes
British Acheson Electrodes, Ltd., Sheffield.

Extruded Rods and Sections
Earle Bourne & Co., Ltd., Birmingham.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes
Addalloy Metal Co. Ltd., 14, Park Lane, Sheffield 10.
Imperial Chemical Industries Ltd., Dept. C. 6, Imperial Chemical House, London, S.W. 1.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations
Addalloy Metal Co. Ltd., 14, Park Lane, Sheffield 10.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Rd., Manchester.
Thos. Wilkinson & Co., Ltd., Middlesbrough.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Elektrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
G. W. B. Electric Furnaces, Ltd., Belgrove House, Belgrove St., London, W.C. 1.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Rd., London, N. 7.

Furnaces (Fuel)
Brayshaw Furnaces Ltd., Manchester.
British Furnaces Ltd., Chesterfield.
Cassel Cyanide Co., Ltd., Room 170r2, Imperial Chemical House, London, S.W. 1.
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
Kasenit Ltd., Holyrood St., Bermondsey St., London, S.E. 1.
King, Taudevin & Gregson, Ltd., Sheffield.
Priest Furnaces Ltd., Albert Road, Middlesbrough.
Salem Engineering Co., Ltd., London.
Wellman Smith Owen Engineering Corporation Ltd., Victoria Station House, London.

Fused Blocks
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.

Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester.
Shorter Process Co., Ltd., Savile St. East, Sheffield.

Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.
I.C.I. Cassel Cyanide.

Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Ironfounders.
Joshua Bigwood & Son, Ltd., Wolverhampton.

Machinery
Joshua Bigwood & Son, Ltd., Wolverhampton.

Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.

Magnesium Alloys
F. A. Hughes Ltd., London.
Magnesium Castings, Ltd., Slough.
Sterling Metals, Ltd., Coventry.

Magnetic Separators, Clutches, Chucks, and Lifting Magnets
Electromagnets, Ltd., 48, High St., Erdington, Birmingham.

Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Non-Ferrous Metals
Birmetals, Ltd.
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
McKechnie Bros. Ltd., Rotton Park St., Birmingham.

Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bradley & Foster, Ltd., Darlaston.

Presses
Eumuco Ltd., Beverley Works, Willow Ave., Barnes, London, S.W. 13.
Schloemann, A.-G., Düsseldorf, Germany.

Protection of Metal Parts for Use at High Temperatures
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.

Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.

Pyrometers
Cambridge Instrument Co., Ltd., London.
Electroflo Meters Ltd., Abbey Rd., Park Royal, London, N.W. 1.
Ether Ltd., Tyburn Rd., Birmingham.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.

Recording Instruments
Cambridge Instrument Co., Ltd., London.
Electroflo-Meters Co., Ltd., Abbey Rd., Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Rd., Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.

Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
Thos. Marshall and Co., Loxley, near Sheffield.
Morgan Crucible Co., Ltd., Battersea Church Rd., London, S.W. 11.
John G. Stein & Co., Bonnybridge, Scotland.

Rolling Mills
Demag, A.-G., Germany.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain: J. Rolland and Co., 2, Victoria St., London, S.W.1
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.-G., Germany.
Karl., Fr. Ungerer., Germany.

Steels
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.
Bochumer Verein A.-G. Germany.
British Rolling Mills Ltd., Tipton.
Crofts (Engineers) Ltd., Bradford.
Daniel Doncaster & Sons, Ltd., Sheffield.
Darwins, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
Edgar Allen & Co. Ltd., Sheffield.
Thos. Firth & John Brown, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Hadfields Ltd., Sheffield.
Mills, Exors of James Ltd., Stockport.
Sanderson Bros. and Newbould, Ltd., Sheffield.
United Steel Companies, Ltd., Sheffield.

Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furness.

Steel Tubes and Sections
Reynolds Tube Co., Tyseley, Birmingham.

Temperature Controllers
Cambridge Instrument Co., Ltd., London.
Electroflo-Meters Co. Ltd., Abbey Rd., Park Royal, London.
Ether, Ltd., Tyburn Rd., Birmingham.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
George Kent, Ltd., Luton.

Testing Machines
Howden, T. C., and Co., 517, Fleet Street, Birmingham.

Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

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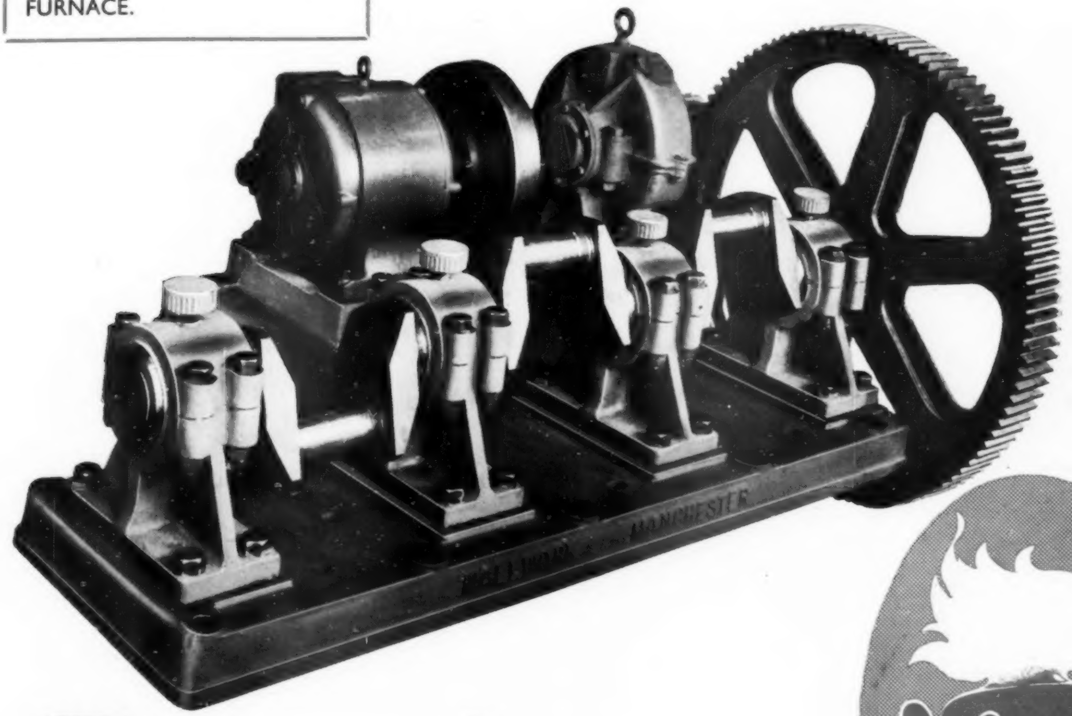
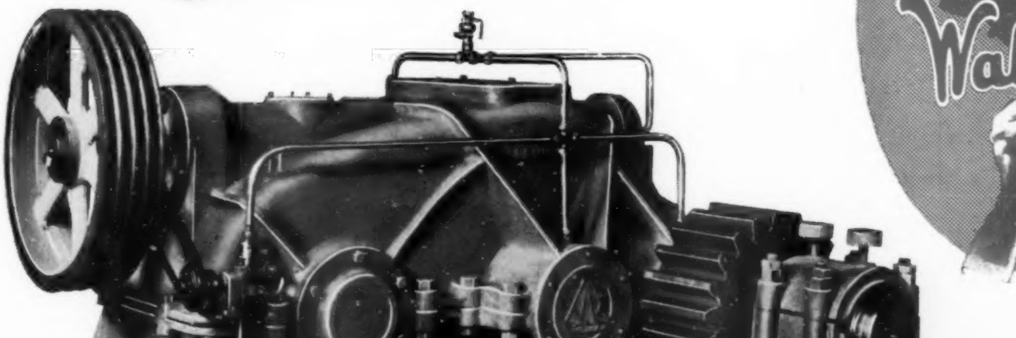
FEEDER DRIVE for CONTINUOUS STEEL BILLET FURNACE.





HEAVY KILN DRIVE

WALLWORK GEARS LTD. MANCHESTER 4

TELEGRAMS "FOUNDRY, MANCHESTER" **TELEPHONES: BLACKFRIARS 1801 (3 lines)**